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THE ASTRONOMICAL OBSERVATORY

OF

HARVARD COLLEGE.

EDWARD C. PICKERING, Director.

CIRCULARS
151 to 200

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HARVARD COLLEGE OBSERVATORY.

CIRCULAR 151.

20 NEW VARIABLE STARS IN HARVARD MAP, No. 49.

Harvard Map, No. 49, which has a centre in R.A. = $9^h\ 00^m$, Dec. = −60°, has been examined for variable stars by Miss Cannon. Besides 20 new variables, which are given in Table I, the following known variable stars were also found: — T Velorum, RW Carinae, Y Velorum, R Carinae, RV Carinae, S Carinae, W Velorum, ST Carinae, *101659*, *102359*, *102458*, *104057*a, *104055*, *104758*, *105160*, *105364*, and *110060*.

TABLE I.

NEW VARIABLE STARS.

Desig.	H. V.	Constellation.	DM.	R.A. 1900.			Dec. 1900.		Bright.	Faint.	Range.
				h.	m.	s.	°	′			
073869	3189	Volans	−69° 756	7	37	57.5	−69	18.9	10.0	10.9	0.9
083343	3190	Vela	−43° 4474	8	33	34.7	−43	46.0	7.5	8.6	1.1
084047	3191	Vela	−46° 4498	8	40	21.1	−47	2.6	8.8	9.8	1.0
084145	3192	Vela	−45° 4490	8	41	31.9	−45	58.6	8.5	9.3	0.8
084150	3193	Vela	−50° 3533	8	41	50.0	−50	11.9	9.7	10.5	0.8
090551	3194	Vela	−50° 3870	9	5	3.2	−51	2.0	8.1	9.0	0.9
091149	3195	Vela	−49° 4237	9	10	58.1	−49	21.5	9.8	10.6	0.8
091550	3196	Vela	−50° 4012	9	15	38.6	−50	8.6	9.9	11.9	2.0
091649	3197	Vela	−48° 4613	9	16	52.6	−49	6.2	8.5	11.0	2.5
092450	3198	Vela	−50° 4168	9	24	7.4	−50	38.0	8.8	10.5	1.7
092849	3199	Vela	−49° 4469	9	28	8.5	−49	12.8	9.2	10.0	0.8
094471	3200	Carina	−71° 873	9	44	39.7	−71	44.8	9.3	10.2	0.9
094559	3201	Carina	..	9	45	18	−59	4.2	10.0	<13.5	>3.5
100054	3202	Vela	−54° 3079	10	0	46.3	−54	43.0	10.0	10.8	0.8
100352	3203	Vela	−52° 3245	10	3	50.9	−52	46.2	9.1	9.9	0.8
101060	3204	Carina	..	10	10	11	−60	23.3	10.0	<15.5	>5.5
101654	3205	Vela	−54° 3497	10	16	55.9	−54	49.1	8.0	10.0	2.0
101860	3206	Carina	−60° 1856	10	17	58.0	−60	34.1	9.1	9.7	0.6
102357	3207	Carina	−57° 3238	10	23	16.7	−57	45.9	9.3	<12	>2.7
104257	3208	Carina	−56° 3777	10	42	7.4	−57	1.3	8.3	10.0	1.7

REMARKS.

07[illegible]. This star is fainter than normal on 3 of 28 photographs examined. It is probably of the Algol type.

083343. The variation was confirmed by an examination of 28 photographs. The period appears to be short. The spectrum is of Class K.

08[illegible]150. The period is probably short.

090551. The period is probably short.

101060. The observations of 50 photographs show that this is a variable star of long period, and give formula for times of maximum, J.D. 2410168 + 231 E.

101860. The variation was confirmed by an examination of 50 photographs. The range is small, but as suitable comparison stars are situated near, the change appears to be real.

102357. The period is probably long.

The successive columns of Table I give the designation of the variable expressed in hours, minutes and degrees, the number in the list of variables discovered at Harvard, the constellation, the number of the star in the Cordoba Durchmusterung for stars north of −52°, or the Cape Photographic Durchmusterung for stars south of −52°, in 1875, the right ascension for 1900, the declination for 1900, the brightest photographic magnitude yet observed, the faintest photographic magnitude yet observed, and the range of the variation. These variables were confirmed on from 15 to 50 photographs, taken with the Bache, as well as the Cooke, Telescope. Those stars showing variation of less than one magnitude, were confirmed by Miss Wells or Miss Leland.

THE VARIABLE STAR, −TAURI, 054319.

The star whose position for 1900 is R. A. = $5^h\ 43^m\ 12^s$, Dec. = +19° 2′.0, and which follows the Durchmusterung star, +19° 1081, about 3^s and is south 0′.2, was announced to be variable by Miss Cannon on July 13, 1908, in H. C. 140. It is also stated in that circular, "The variation is large, but it appears uncertain whether this star belongs to Class II, variables of long period, or is peculiar and resembles R Coronae Borealis." The latter view is confirmed and measures of this object have been made by Miss C. E. Burns on 408 Harvard photographs, taken between December 16, 1885 and December 14, 1908. During this period of time, only four minima are shown on the photographs. The first of these minima occurred in February, 1891, but its duration has not been determined, since there is no photograph between February 22, 1891, when the star was invisible and fainter than magnitude 12.4, and November 13, 1891, when it was magnitude 10.3, full brightness. The next minimum lasted from December, 1898 to December, 1899, the third from September, 1904 to August, 1905, and the fourth, which commenced in November, 1908, is still in progress. No trace of the star was visible on a plate taken September 6, 1909, and showing stars of the magnitude 12.5. The photographic magnitude at maximum is about 10.3. The light is often nearly constant for several years. Thus, 112 photographs well distributed between February 15, 1900 and April 12, 1904, show the star to be at or near maximum brightness. The minimum magnitude is evidently very faint. No trace of the star is seen on two good plates taken with the Bruce Photographic Telescope and showing stars as faint as the magnitude 15. The star was looked for by Miss Cannon, but was not visible in the 6-inch Telescope of this Observatory in December, 1908, January, February and March, 1909. It was not seen by Mr. Leon Campbell with the 24-inch Reflector on April 10 and April 22, 1909, and was probably fainter than the magnitude 14 on these dates.

The following tables give, in a condensed form, the principal facts concerning the star as photographed here. Table II gives the number of plates on which the star was observed at full brightness. The first column gives the year, the second the number of plates in that year, and the third, the mean magnitude.

TABLE II.

OBSERVATIONS AT FULL BRIGHTNESS.

Year.	No.	Magn.	Year.	No.	Magn.	Year.	No.	Magn.
1886	8	10.24	1894	3	10.27	1902	30	10.34
1887	2	10.15	1895	3	10.17	1903	35	10.32
1889	4	10.32	1896	4	10.25	1904	13	10.31
1890	2	10.35	1897	4	10.30	1905	22	10.33
1891	7	10.29	1898	6	10.23	1906	34	10.27
1892	1	10.30	1900	19	10.59	1907	16	10.29
1893	3	10.30	1901	21	10.39	1908	12	10.25

It will be seen that the magnitude was nearly constant on the 249 plates included in Table II. The faintest mean magnitude occurred in 1900, and may be due to the incomplete recovery of the star from the long minimum phase, lasting from December, 1898 to December, 1899.

Table III gives a few of the dates, Julian Days, and magnitudes when this star was faint or invisible on the photographs examined. The last observation at full brightness preceding the minimum and the first following the minimum, are also given, except for the last minimum, which is still in progress. Italics indicate that the star was invisible, and fainter than the given magnitude. Thus, on October 16, 1898, the star was of normal brightness, magnitude 10.2, on December 15, 1898, it was invisible and fainter than magnitude 11.3, on December 23, 1898, it was invisible and fainter than magnitude 12.7, and on May 16, 1899, the last photograph obtained before the star's conjunction with the Sun, it was fainter than magnitude 11.8. When again photographed in September, 1899, the object was still faint and on October 11, 1899, an excellent Bruce photograph shows no trace of the star, although stars of magnitude 15.5 are visible. On November 25, 1899, it was visible, magnitude 12.4, and with some fluctuations regained full brightness by February 15, 1900.

TABLE III.

OBSERVATIONS AT OR NEAR MINIMUM.

Date.	J. D.	Magn.	Date.	J. D.	Magn.	Date.	J D.	Magn.
90 12 29	11731	10.2	99 10 11	14939	*15.5*	04 12 11	16826	*12.4*
91 2 13	11777	*11.8*	“ “ 14	14942	*12.5*	“ “ 14	16829	*11.8*
“ “ 22	11786	*12.4*	“ “ 27	14955	*13.0*	“ “ 28	16843	*11.8*
“ 11 13	12050	10.2	“ 11 25	14984	12.4	05 1 28	16874	*12.4*
98 10 16	14579	10.2	“ “ 30	14989	12.5	“ 3 4	16909	*11.8*
“ 12 15	14639	*11.3*	“ 12 13	15002	12.4	“ 4 6	16942	*10.9*
“ “ 23	14647	*12.7*	00 2 15	15066	10.3	“ 8 31	17089	10.5
99 1 12	14667	*12.9*	04 4 12	16583	10.3	“ 9 8	17097	10.2
“ “ 18	14673	*12.4*	“ 9 15	16739	*11.8*	08 4 16	18048	10.2
“ 3 29	14743	*12.8*	“ 10 15	16769	*11.3*	“ 11 5	18251	*12.4*
“ “ 30	14744	*12.7*	“ “ 22	16776	*11.3*	09 8 22	18541	*12.0*
“ 4 1	14746	*12.9*	“ 11 14	16799	*12.3*	“ 9 6	18556	*12.5*
“ 5 16	14791	*11.8*	“ “ 16	16801	*13.9*			

The light curve of this star resembles that of R Coronae Borealis in having long periods of normal light, followed by sudden diminutions of large range, and thus another star is added to that rare class of variables of which only R Coronae Borealis and RY Sagittarii have hitherto been known.

EDWARD C. PICKERING.

SEPTEMBER 8, 1909.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 152.

20 NEW VARIABLE STARS IN HARVARD MAP, Nos. 2, 5, 32, 44, AND 53.

THE following table gives a list of twenty variables found by Miss E. F. Leland from an examination of Nos. 2, 5, 32, 44, and 53 of the Harvard Map of the Sky. One new variable was found in H.M. 2 which has a centre in R.A. 0^h, Dec. +60°; two in H.M. 5, R.A. 9^h, Dec. +60°; five in H.M. 32, R.A. 20^h, Dec. 0°; nine in H.M. 44, R.A. 20^h, Dec. −30°; three in H.M. 53, R.A. 21^h, Dec. −60°. Besides these, the following known variable stars were also found. In H.M. 2, T Cephei, W Cephei, V Cassiopeiae, R Cassiopeiae, T Cassiopeiae, and δ Cephei. In H.M. 5, R Ursae Majoris, W Ursae Majoris, Y Draconis, and RS Camelopardalis. In H.M. 32, R Aquilae, U Sagittae, X Aquilae, and SS Aquilae. In H.M. 44, RU Sagittarii, RR Sagittarii, R Microscopii, RT Sagittarii, and S Microscopii. In H.M. 53, RU Sagittarii and RZ Sagittarii.

In Table I, the designation of the variable, the H.V. number, or number in the order of discovery here, the constellation, the Durchmusterung number, the right ascension for 1900, and the declination for 1900 are given in the first six columns. The magnitudes of the brightest image and of the faintest image, as indicated by the photographs so far examined, are given in the seventh and eighth columns. These are not standard magnitudes, but are approximate and are found by the method described in H.A. 47. The difference between these two magnitudes, or the range of variation, is given in the ninth column. The Class of Variable is given in the tenth column, II indicating a variable of long period; IV, a variable of short period; V, a variable of the Algol Type.

If we assume that the number of known variables found is to the total number found, as the number already known is to the whole number in the region, it follows that in H.M. 2 there are probably 32 variables, of which 28, or 0.88, have been discovered. In H.M. 5 there are probably 14 variables, of which 11, or 0.79, have been discovered. In H.M. 32 there

TABLE I.

NEW VARIABLE STARS.

Desig.	H. V.	Constellation.	DM.	R.A. 1900.			Dec. 1900.		Bright.	Faint.	Range.	Class.
				h.	m.	s.	°	′				
084849	3209	Ursa Major	+50° 1590	8	48	20	+49	52.2	10.0	11.0	1.0	. .
104055	3210	Ursa Major	+55° 1409	10	40	19	+55	34.3	8.2	9.7	1.5	. .
181146	3211	Telescopium	−46° 12279	18	11	22	−46	35.3	9.5	<12.0	>2.5	II?
185639	3212	Corona Australis	−39° 13082	18	56	20	−39	42.6	10.0	<13.0	>3.0	II?
191340	3213	Sagittarius	R	19	13	10	−40	23.1	10.0	<13.0	>3.0	II?
191739	3214	Sagittarius	. .	19	17	50	−39	26.8	10.0	<13.0	>3.0	II?
191935	3215	Sagittarius	. .	19	19	37	−35	32.8	9.5	12.2	2.7	II
192201	3216	Aquila	+ 1° 4003	19	22	33	+ 1	50.7	9.8	<13.5	>3.7	II
192238	3217	Sagittarius	−38° 13504	19	22	43	−38	17.5	10.0	<13.0	>3.0	II?
193245	3218	Telescopium	. .	19	32	22	−45	48.3	9.2	<13.5	>4.3	II
193742	3219	Sagittarius	. .	19	37	16	−42	5.4	9.0	13.2	4.2	II
194613	3220	Aquila	. .	19	46	24	+13	42.6	10.6	12.7	2.2	IV
200103	3221	Aquila	. .	20	1	38	+ 3	34.4	9.0	10.8	1.8	IV
200706	3222	Aquila	. .	20	7	58	+ 6	0.1	10.0	13.9	3.9	II
200913	3223	Capricornus	. .	20	9	21	−13	15.1	9.6	<11.0	>1.4	. .
201217	3224	Capricornus	−18° 5641	20	12	14	−17	59.3	8.8	10.6	1.8	V
205148	3225	Indus	−48° 13729	20	51	12	−48	27.4	9.4	10.2	0.8	. .
210445	3226	Indus	−45° 14237	21	4	51	−45	29.0	7.9	9.5	1.6	. .
214750	3227	Indus	−50° 13517	21	47	52	−50	24.9	10.3	11.6	1.3	. .
222656	3228	Cepheus	+56° 2793	22	26	22	+56	28.9	9.2	10.8	1.6	. .

REMARKS.

185639. The variable is the southern and preceding of two close stars, either or both of which might be identified as C. DM. −39° 13082.

191340. This star is C. P. D. −40° 8913, and is not in the C. DM.

191935. Measures of 97 photographs, taken between August 6, 1889 and May 20, 1908, show that this is a variable of long period, and give the formula for times of maximum, J.D. 2410186 + 197^{d} E.

192201. Measures of 72 photographs, taken between August 1, 1890 and May 12, 1907, show that this is a variable of long period, and give the formula for times of maximum, J.D. 2410220 + 270^{d} E.

193245. Measures of 126 photographs, taken between June 19, 1889 and July 31, 1907, show that this is a variable of long period, and give the formula for times of maximum, J.D. 2410077 + 230^{d} E.

193742. Measures of 77 photographs, taken between June 8, 1892 and October 16, 1907, show that this is a variable of long period, and give the formula for times of maximum, J.D. 2410184 + 263^{d} E.

194613. Measures of 62 photographs, taken between June 2, 1890 and November 14, 1905, show that this star is a variable of short period.

200103. Measures of 78 photographs, taken between July 15, 1897 and July 18, 1906, show that this star is a variable of short period.

200706. Measures of 50 photographs, taken between August 19, 1891 and July 18, 1906, show that this star is a variable of long period, and give the formula for times of maximum, J.D. 2410028 + 240^{d} E.

201217. This star was examined on 100 photographs. On August 1, 1900, May 14, 1902, August 19, 1904, June 10, 1905, August 15, August 19, and November 8, 1906, it was a magnitude fainter than the normal magnitude, 9.3.

are probably 61 variables, of which 32, or 0.52, have been found. In H.M. 44 there are probably 64 variables, of which 32, or 0.50, have been discovered. In H.M. 53 there are probably 42 variables, of which 20, or 0.48, have been discovered.

Several of these stars were measured by Miss Leland on a large number of plates, and the elements given below were derived, by Miss Cannon, from these measures.

EDWARD C. PICKERING.

JANUARY, 14, 1910.

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HARVARD COLLEGE OBSERVATORY.

CIRCULAR 153.

OPPOSITION OF EROS (433) IN 1910.

The orbit of Eros (433) is so remarkable, that frequent measures of its position should be obtained. Its light also varies according to peculiar and unknown laws and, therefore, measures of its brightness should be made at short intervals. Although it comes to opposition on May 23, 1910, no ephemeris of it appears to have been published. Accordingly, Professor Wendell has computed the ephemeris given in Table I, which furnishes the position of Eros during the entire time that it can be conveniently observed, from before the first stationary point until after the second stationary point. The object of an ephemeris is to furnish the observer with all the material he needs, in a form which can be used directly and without computation. It is unfortunate, therefore, that it is customary to publish ephemerides for faint objects in apparent place, or for the beginning of the current year. These positions, as published, are of little value to the observer, since such objects cannot be observed with a transit instrument, and it would generally be useless to attempt to find them by direct settings with an equatorial. In practice, an observer, using either an equatorial or photographic telescope, must first reduce the position to 1855, if the object is north of −23°, or to 1875, for southern objects. He can then find the object directly by comparison with the stars in the northern or southern Durchmusterung. A step in this direction has been made, by the Berlin Rechen-Institut, which gives the means of making this reduction approximately, in each case. In Table I, the successive columns give the year, month, and day, the Julian Day, the right ascension for 1910.0, the declination for 1910.0, the right ascension for 1875.0, the declination for 1875.0, the logarithm of the distance from the Sun, the logarithm of the distance from the Earth, and the computed magnitude. The assumed value of g, the magnitude of Eros at distance unity from the Sun and Earth, is 9.7, as given in the Berlin Jahrbuch.

TABLE I.

EPHEMERIS OF EROS (433).

Date.			Julian Day.	R. A. 1900.		Dec. 1900.		R. A. 1875.		Dec. 1875.		Log. *r*.	Log. *Δ*.	Magn.
y.	*m.*	*d.*	*d.*	*h.*	*m.*	°	′	*h.*	*m.*	°	′			
1910	3	19	8750	16	38.0	−42	42	16	35.5	−42	38	0.137	9.867	10.62
"	4	8	8770	16	57.4	−46	30	16	54.8	−46	27	0.157	9.824	10.50
"	"	18	8780	16	56.3	−47	55	16	53.7	−47	52	0.166	9.803	10.45
"	"	28	8790	16	46.8	−48	46	16	44.2	−48	42	0.175	9.785	10.40
"	5	8	8800	16	29.8	−48	44	16	27.2	−48	40	0.184	9.773	10.39
"	"	18	8810	16	8.2	−47	33	16	5.7	−47	28	0.192	9.772	10.42
"	"	23	8815	15	57.4	−46	31	15	54.9	−46	25	0.196	9.775	10.46
"	"	28	8820	15	47.2	−45	14	15	44.8	−45	7	0.200	9.782	10.51
"	6	7	8830	15	30.8	−42	8	15	28.4	−42	1	0.207	9.805	10.66
"	"	17	8840	15	21.0	−38	49	15	18.7	−38	42	0.214	9.838	10.86
"	"	27	8850	15	17.7	−35	44	15	15.5	−35	36	0.220	9.878	11.09
"	7	7	8860	15	19.9	−33	6	15	17.7	−32	59	0.225	9.922	11.34
"	8	6	8890	15	49.5	−28	12	15	47.3	−28	5	0.238	0.053	12.06

It is unfortunate that one of the national almanacs does not give a continuous ephemeris of Eros, in a form like the very convenient ephemerides of the four larger asteroids, published in the British Nautical Almanac. The only additional data needed in all these ephemerides is the phase angle, or the angle between the Sun and Earth as seen from the asteroid. This element has not been given in Tables I and II, since no use will be made of it, unless photometric observations of these asteroids are obtained. A convenient method of computing it will be found in H.A. 18, 38.

EPHEMERIDES OF BRIGHT ASTEROIDS.

Every year several of the asteroids, besides the first four discovered, become brighter than the tenth magnitude, yet there is no easy method of finding them, except by the position and daily motion at opposition, given in the Supplement to the Berlin Jahrbuch. Four of these asteroids are now conveniently situated for observation, and ephemerides have accordingly been computed for them by Mr. F. E. Seagrave, and are given in Table II in the same form as Table I. In computing the magnitudes, the values of *g* in the four cases have been assumed to be 5.8, 6.3, 5.4, and 6.5, respectively, as given in the Berlin Jahrbuch.

TABLE II.

EPHEMERIDES OF BRIGHT ASTEROIDS.

Date.			Julian Day.	R. A. 1910.		Dec. 1910.		R. A. 1855.		Dec. 1855.		Log. r.	Log. Δ.	Magn.
Hebe (6).														
y.	m.	d.	d.	h.	m.	°	′	h.	m.	°	′			
1910	2	6	8709	10	53.6	+12	42	10	50.7	+13	0	0.435	0.253	9.24
"	"	16	8719		45.8	+14	26		42.9	+14	43	0.438	0.246	9.22
"	"	26	8729		36.9	+16	9		34.0	+16	26	0.440	0.248	9.24
"	3	8	8739		28.1	+17	41		25.1	+17	58	0.442	0.256	9.29
"	"	18	8749		20.4	+18	56		17.4	+19	13	0.444	0.271	9.38
Metis (9).														
y.	m.	d.	d.	h.	m.	°	′	h.	m.	°	′			
1910	1	23	8695	9	58.5	+21	52	9	55.4	+22	8	0.348	0.110	8.59
"	2	2	8705		49.5	+23	2		46.4	+23	17	0.351	0.104	8.58
"	"	12	8715		39.2	+24	3		36.1	+24	18	0.353	0.106	8.59
"	"	22	8725		29.2	+24	47		26.0	+25	2	0.356	0.117	8.66
"	3	4	8735		20.9	+25	9		17.7	+25	23	0.358	0.136	8.77
Hygeia (10).														
y.	m.	d.	d.	h.	m.	°	′	h.	m.	°	′			
1910	2	6	8709	10	50.1	+ 2	58	10	47.3	+ 3	16	0.481	0.324	9.42
"	"	16	8719		43.3	+ 3	25		40.5	+ 3	42	0.479	0.311	9.35
"	"	26	8729		35.6	+ 4	1		32.8	+ 4	18	0.478	0.305	9.32
"	3	8	8739		27.8	+ 4	41		25.0	+ 4	58	0.476	0.304	9.30
"	"	18	8749		20.7	+ 5	20		17.8	+ 5	37	0.475	0.310	9.32
Marsalia (20).														
y.	m.	d.	d.	h.	m.	°	′	h.	m.	°	′			
1910	2	11	8714	11	15.4	+ 3	48	11	12.6	+ 4	6	0.339	0.098	8.68
"	"	21	8724		7.6	+ 4	38		4.8	+ 4	56	0.342	0.088	8.65
"	3	3	8734	10	58.5	+ 5	38	10	55.7	+ 5	56	0.345	0.086	8.66
"	"	13	8744		49.4	+ 6	38		46.5	+ 6	56	0.348	0.094	8.71
"	"	23	8754		41.8	+ 7	29		38.9	+ 7	46	0.350	0.111	8.80

It will be noticed that the position given for Metis on February 12, in Table II, precedes that given in the Berlin Jahrbuch by $2^m.1$, and is north 16′. The epoch of osculation is June 30.0, 1858, and it is probable that a correction based on recent observations has been applied in the Jahrbuch. The differences in the case of the other asteroids are small.

EDWARD C. PICKERING.

February 16, 1910.

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CIRCULAR 154.

DETERMINATION OF ABSOLUTE WAVELENGTHS WITH OBJECTIVE PRISMS.

NEARLY all of the photographs of stellar spectra, made by the aid of the Henry Draper Memorial, have been taken with objective prisms. The principal objection to this method of photographing the spectra of stars has been that it does not provide the means of determining their velocities in the line of sight. Various methods of remedying this difficulty have been tried here, and were described in 1891, in H.A. 26, xxi. Among these methods are absorption by didymium and hyponitric acid, variation in length of a known portion of the spectrum, and the use of an auxiliary prism. The first of these methods appeared to be the simplest and best, but the absorption bands were too wide and hazy for precise measurement. The second method was then shown to be impracticable, but has since been recommended by Orbinskij, and is commonly ascribed to him. Another method, turning the prism 180°, was proposed in H.C. 110, and is now generally regarded as the best method yet proposed.

After discussing this problem with Professor Robert W. Wood of Baltimore, at my request, he prepared the following statement: —

" My attention was drawn recently by Professor E. C. Pickering to the great need of a ray filter giving one or more sharp and narrow absorption lines, for the determination of stellar velocities with the objective prism.

It occurred to me that the 4272 band of neodymium might answer the purpose. In a solution of the double nitrate of neodymium and ammonium (now procurable in large quantities as a by product in the manufacture of Welsbach mantles) I found that the band was much too wide for use in the determination of stellar velocities. The solution of the pure chloride however was quite different, for the band was found to have contracted to a width of less than three Angström units and its centre could easily be determined to within 0.15 A.E. The absorption spectrum was photographed with a concave grating of 7 feet radius, together with the iron spectrum, and it was found that wave length determinations, referred to the neodymium line could be determined certainly to within 0.10 A.E. This would enable stellar velocities to be determined to within less than 10 kilometres per second. The strength of the solution must be regulated according to the thickness of the cell. For a cell 4mm. in thickness I diluted a saturated solution with about five parts of distilled water. It is very easy to determine the proper strength by trial. It may be possible to still further contract the band, by the addition of some other substance. It has been found that lanthanum increases the sharpness of some of the didymium bands, also phosphoric acid. Experiments in this direction are in progress. The photograph of the absorption line with a rough scale of wavelengths and the iron spectrum is reproduced in Figure 1. The absorption line is almost in coincidence with the close double line of iron at wavelength 4271.5."

Professor Wood has also kindly filled a ray filter with the solution named above, and a number of stellar spectra have been photographed through it. Figure 2 represents a photograph of the Pleiades taken with the 8-inch Draper Telescope, on February 14, 1910, exposure 54^m, enlarged 2.72 times. The other spectra were photographed with the 11-inch Draper Telescope, and were enlarged 1.56 times. The lengths of exposure are those of the portion of the photograph shown in the plate. Figure 3 represents the spectrum of α Canis Minoris taken with and without the cell interposed, on February 18, 1910, each exposure being 21^m. Figure 4 represents the spectrum of H.R. 1876, ϕ^1 Orionis, taken February 18 with an exposure of 55^m. Figure 5 represents the spectrum of H.R. 2088, β Aurigae, taken February 19, 1910, with an exposure of 17^m. This star is a spectroscopic binary and the stellar lines have become double, as may be seen in line K in the original negative. The neodymium line of course remains single. Figure 6 represents the spectrum of H.R. 1713, β Orionis, taken February 19, 1910, with an exposure of 8^m.

It will be seen from Figure 2 that a large number of spectra may be photographed on a single plate, with sufficient distinctness to enable the lines to be measured with accuracy. This is also shown in H.A. 26, Plate VII. Several absorption bands are shown in Figure 3, but only one, $\lambda = 4272$, is sufficiently well defined to be satisfactorily measured. It occurs in a very convenient place, in the brightest part of the spectrum, between

5. 2a

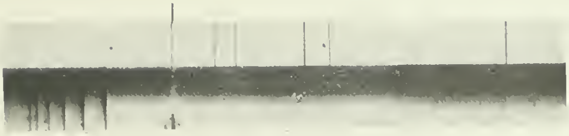

Fig. 1. Spectra with Grating.

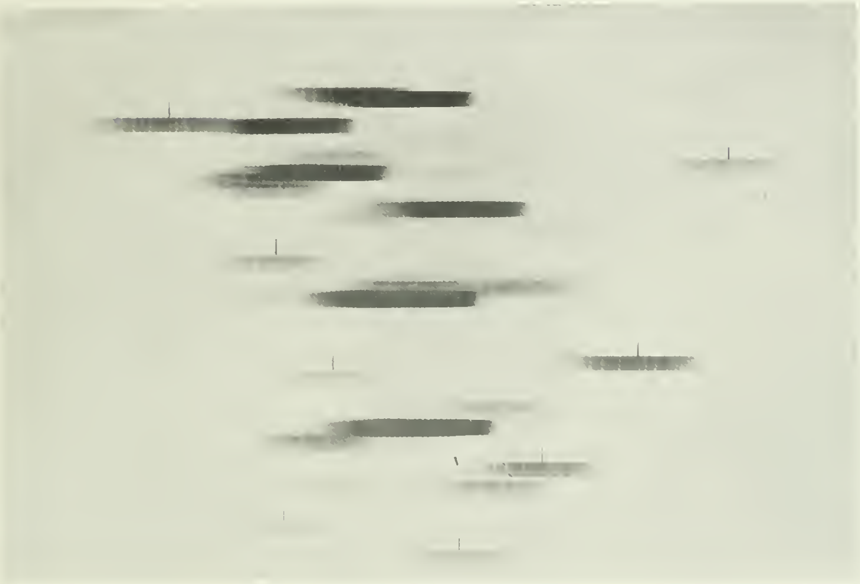

Fig. 2. Pleiades.

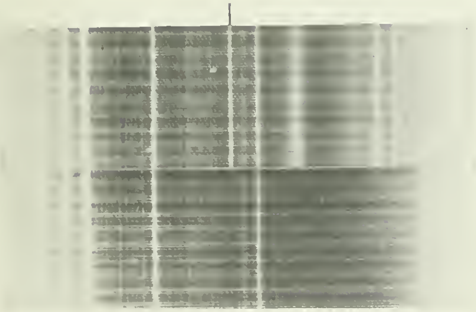

Fig. 3. α Canis Minoris.

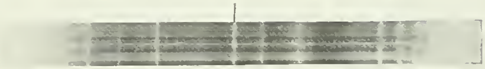

Fig. 4. ϕ^1 Orionis.

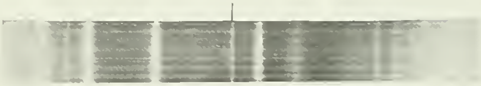

Fig. 5. β Aurigae.

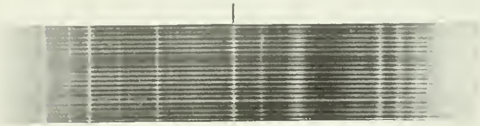

Fig. 6. β Orionis.

ABSORPTION OF NEODYMIUM CHLORIDE.

the lines Hδ and Hγ. It is marked by a black line on several of the spectra. The lines in the spectrum of β Orionis, Figure 6, are well defined, and can be measured with accuracy. It will be seen that the neodymium line appears to be at least as sharp as the hydrogen lines in this star, or as the calcium line, K.

The determination of the approximate motion of stars in the line of sight in this way becomes very simple. It is only necessary to measure the distance of the neodymium line, 4272, from Hδ, 4101, and Hγ, 4340, and perhaps from some of the other lines, and then to derive their wavelengths, by Hartmann's formula, assuming the neodymium line to be constant. The actual determination with sufficient accuracy to render this method of value, however, is a very different matter. While it is not probable that it can compete with the slit spectroscope in determining the motions of the brighter stars, it may be worth while to compare the advantages of each, and thus see how far the new method may be useful in supplementing the old. This cannot be decided until this method receives the same careful study which has been made of the slit spectroscope.

The principal objections to the slit spectroscope are, first, the great loss of light. It is maintained that less than one per cent of the entire light falls upon the sensitive plate. Accordingly, only the brightest stars can be measured with accuracy, and even for these it is necessary to use the largest telescopes yet constructed. A second objection is, the great rigidity required, and the necessity of maintaining a perfectly uniform temperature. The simplicity of the method of the objective prism renders it probable that the sources of error are few in number, and therefore readily corrected. The loss of light is small, so that very faint spectra can be photographed. The principal work so far done with the slit spectroscope has been with stars of the fifth magnitude, and brighter.

In the Harvard Circulars announcing peculiar spectra it will be noticed that many of the stars are not contained in either the northern, or the southern Durchmusterung, and must therefore be fainter than the tenth magnitude. These spectra however have well marked bands or bright lines, which are easily seen. From the classification of the spectra of stars in clusters given in H.A. 26, Chapter XIV, it does not seem unreasonable to expect that the spectra of stars of the first type as faint as the ninth magnitude can be photographed with sufficient detail to determine the approximate approach and recession. Plate VII of H.A. 26 is an example of a plate taken with an objective prism. The distance between the lines Hδ and Hγ is here about 1.6 mm. On this scale 1 A.E. would equal $1''.2$, corresponding to 75 km. An error of $\pm 0''.1$ would therefore represent ± 6 km. Preliminary measures of the three lines in the spectra of five stars photographed with the 11-inch Draper Telescope gave a probable error of 10, 7, and 11 km. for the mean of five settings on the lines 4101, 4272, and 4340, respectively. It will be noticed that the error in the case of the neodymium line is distinctly less than those of the hydrogen lines. The only lines that can be photographed in faint stars whose spectra are of the first type are those of hydrogen. As they are wider than the neodymium line, this limits the accuracy with which such stars can be measured. Spectra of the second or third type must be much brighter to show measurable lines, but when these are visible, greater accuracy may be expected. The agreement of the various estimates given above renders it probable that, with our present means, we can determine the motion of a ninth magnitude star of the first type with an error of about 10 km., and of an eighth magnitude star of the second type with somewhat greater accuracy. Much wider spectra are needed to classify spectra, than to measure the position of the lines. Unfortunately, when objective prisms are used, if long exposures are made producing narrow spectra the definition is poor.

The Henry Draper Memorial has furnished the Harvard Observatory with excellent means for photographing stellar spectra with objective prisms. At Cambridge, prisms are available for covering the mirrors or objectives of the following instruments: — 24-inch Reflector, interval Hδ to Hγ, 0.5 mm., scale $60'' = 1$ mm.; 16-inch Metcalf Telescope (doublet), prism under construction; 11-inch Draper Telescope, two prisms giving intervals 5.5 and 11.5 mm., scale $54'' = 1$ mm.; 8-inch Draper (doublet), two prisms giving intervals 0.0 to 1.7 mm., scale $162'' = 1$ mm. At Arequipa, 24-inch Bruce Telescope (doublet) interval 1.7 mm., scale $60'' = 1$ mm.; 13-inch Boyden Telescope, two prisms, intervals 7.3 and 13.9 mm., scale $42'' = 1$ mm.; 8-inch Bache telescope, two prisms, intervals 1.7 and 0.6 mm., scale $178'' = 1$ mm.

With this equipment, the Harvard Observatory is prepared to take such photographs as may be desired, and it invites the aid of astronomers experienced in measurements in the line of sight.

EDWARD C. PICKERING.

March 12, 1910.

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CIRCULAR 155.

ACCURATE MEASUREMENT OF PHOTOGRAPHS.

THE accuracy with which positions of the stars may be determined from photographs depends on the accuracy with which the eye estimates the equality of two quantities. The errors from this source are far greater than those of a micrometer of high grade. The magnifying power used does not generally exceed twenty or thirty diameters, since with a high power the individual silver particles are seen, and the photographic image of a star resembles a star cluster, whose centre is difficult to estimate. When the images are not circular, owing to imperfect following or distortion due to the image not being in the centre of the field of the telescope, these errors are greatly increased, and large systematic errors are introduced, whose amount depends on the position of the star, its brightness, and various other causes. Similar errors arise in measuring the intensity of stellar images.

Five cases may be considered, the position of a circular stellar image, the position of a line in the spectrum, the intensity of a stellar image, the intensity of a line in the spectrum, and the intensity of a surface. In each of these cases it appears possible to substitute, for an eye estimate, an automatic method in which the deviation of a galvanometer needle, or its equivalent, replaces the eye. A rigorous determination, free from personal equation, should thus be secured. Distortion of the images might doubtless introduce errors, but they would always be the same for similar images, or for successive measures of the same image.

Four instruments suggest themselves, the thermopile, the bolometer, the radiometer, and the selenium cell. All of these instruments are capable of measuring exceedingly minute radiations, and then require very delicate adjustment; but when, as in the present case, intense radiations are available, their manipulation is comparatively simple.

As the conditions will vary with the different instruments and methods of measurement, a single case will first be considered, that of the measurement of the positions of the stars with a bolometer. The two sensitive arms of the bolometer are placed side by side, at right angles to the axis of the screw of the measuring machine, and separated at a distance less than the diameter of the faintest image of a star. An incandescent lamp or other source of heat is placed below the photograph and the bolometer immediately above it and close to the film. The bolometer is balanced so that there is no deviation of the galvanometer when the light is in use, and the film, interposed. If now the image of a star is slowly interposed by means of the screw, a portion of the heat is cut off from one arm of the bolometer and the spot of light of the galvanometer darts to one side. It moves to the other side as soon as more heat falls on the other arm. It comes to rest at the zero when the image is so placed, that the silver particles on the edges of the image cut off exactly the same amount of heat from the two arms. A second bolometer placed at right angles to the first serves to measure the other coordinate. If the original images are too small, they may be enlarged by a microscope objective. If an enlarged positive is used, instead of the original negative, the images will be larger, and they will be bright on a dark background. As it is not necessary that the source of light should be constant, daylight may be substituted for the incandescent light.

The conditions for measuring the positions of the lines in the spectrum are much more favorable than in the case of a stellar image. The method is nearly the same, but the length of the sensitive arms may then be nearly equal to the breadth of the spectrum. In this case, many hundreds of silver particles will intercept the heat falling on each arm of the bolometer, and the accidental errors will thus become exceedingly small. If the lines to be measured are broad or hazy, it is only necessary to separate the two arms so that they shall intercept the portions of the edges where the light is varying most rapidly. If the lines are unsymmetrical, sharper on one side than the other, consistent measures can still be made. They may require a constant correction, but the results for a spectroscopic binary on different nights will still be comparable. This method appears to have especial value for terrestrial spectra where there is plenty of light, since, by increasing the width, the effect of the grain may be almost completely eliminated.

To measure the intensity, or photographic magnitude, a contact print or enlarged negative should be employed. A single broad sensitive arm may be used, so that the entire light transmitted by the image may be received on it. This should be counterbalanced by a second arm which may be moved towards the source of light by a micrometer screw. It is probable that much smaller differences in light can be detected in this way, than by the best photometric measures, with the advantage that the results will be free from the large systematic errors by which ordinary photometric measures are likely to be affected.

Measures of the intensity of lines in the spectrum would furnish results of great value. This is shown in H. C. 72, and H. A. 48, No. 9. The measures could be made as described in the preceding paragraph, comparing the amount of light transmitted by the images of different dark lines. In the case of bright lines, contact prints or enlargements could be used. The great advantage of this method is that consistent measures could be obtained of lines unlike in appearance.

The measurement of the light transmitted by a surface would be even simpler than in the case of a point or line, and would be made in the same way.

Comparing the different instruments that could be used, minute thermopiles, or selenium cells, could replace the sensitive arms of a bolometer. It might be difficult to make two radiometers small enough to measure the two sides of a line in the spectrum. The latter could however be greatly enlarged by a microscope objective, and in measuring intensities an important advantage would be found in the simplicity of a radiometer.

One of the most important problems to which this method could be applied would be to determine the approach and recession of faint stars by the absorption line of neodymium, described in H. C. 154. For this purpose the bolometer appears to be the best instrument. It is believed by the writer, that the motions of faint stars could thus be measured with an accuracy comparable with that now attained for bright stars by the slit spectroscope. The photographic magnitudes of stars could also be determined with great precision, especially if the method of multiple images described in H. C. 29 was used. The radiometer would probably be the best instrument in this case.

It is evident that the best solution of this problem should be left to the physicist with all the appliances of a physical laboratory at his command, rather than to an astronomer. It is suggested that it would furnish a student in physics with an excellent subject for a graduating thesis. The necessary apparatus could probably be provided, which could then be put into daily use in an astronomical observatory for the long series of routine observations which would be needed to secure results of permanent value.

EDWARD C. PICKERING.

March 21, 1910.

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CIRCULAR 156.

COMPARISON STARS FOR HALLEY'S COMET.

THE photometric catalogues of this Observatory furnish the magnitudes of a large number of stars with which Halley's Comet may be compared. There are 10 stars in H.A. 50, 85 in H.A. 54, and 13 in H.A. 70, within about one degree of the path of the Comet from January 1 to March 8, 1910. On the last date the Comet was too near the Sun for observation. On April 10, it will precede the Sun, and be far enough away from it to be observed in the morning. Between that date and May 27, 1910, there are 94, 105, and 194 stars within one degree of its path, in the three catalogues, respectively.

As other and fainter stars were needed for observing the Comet in the early part of 1910, additional comparison stars are included in Table I. Measures of a large part of them were made by the writer with the 12-inch Meridian Photometer. The method of measurement was substantially the same as that employed in H.A. 70. The successive columns give a number for reference, the designation in the Bonn Durchmusterung, the right ascension for 1900, the declination for 1900, the magnitude in the Durchmusterung, and the magnitude as found with the 12-inch Photometer. The last column gives the difference found by subtracting the magnitude given in the sixth column from that given in H.A. 54, when the star occurs in that work, and shows how far the errors, both systematic and accidental, are eliminated. These stars were used as standards for deriving the magnitudes, differentially, of the other stars. A few of the later stars were not measured because they were too faint, and a few of the earlier stars, because they were not selected until they were too near the Sun for observation this year. Generally, each star was observed on at least two nights, two sets of four settings each being made on each night.

The average value of the 26 differences in the last column, is ±0.10, and includes the errors in the measurements with both photometers. The magnitude of star 1 in H.A. 54 is 7.29.

TABLE I.

PHOTOMETRIC MAGNITUDES.

No.	DM. No.	R.A. 1900.	Dec. 1900.	DM. Magn.	Photom. Magn.	Diff.	No.	DM. No.	R.A. 1300.	Dec. 1900.	DM. Magn.	Photom. Magn.	Diff.
		h. m.	° ′						h. m.	° ′			
1	+ 8° 64	0 26.4	+ 8 36	7.5	. .	.	42	+ 8° 218	1 17.9	+ 8 39	7.9	7.16	.
2	+ 8° 80	31.2	+ 8 20	7.9	. .	.	43	+ 8° 222	18.5	+ 8 51	9.3	10.76	.
3	+ 7° 83	33.2	+ 8 3	8.0	7.96	.	44	+ 8° 224	18.6	+ 8 49	9.0	9.66	.
4	+ 7° 84	33.3	+ 7 43	8.8	8.26	.	45	+ 8° 229	20.3	+ 8 47	9.2	9.83	.
5	+ 7° 87	34.1	+ 7 39	9.0	9.32	.	46	+ 8° 232	20.6	+ 8 51	8.8	9.31	.
6	+ 7° 89	34.3	+ 7 40	9.1	9.33	.	47	+ 9° 167	20.7	+ 9 53	6.8	7.40	*.18*
7	+ 7° 90	34.5	+ 7 34	8.1	. .	.	48	+ 8° 238	24.0	+ 9 8	8.3	8.36	.
8	+ 7° 100	37.8	+ 8 1	8.6	8.67	.	49	+ 9° 174	24.2	+ 9 22	9.5	11.00	.
9	+ 7° 106	41.7	+ 7 46	9.0	9.31	.	50	+ 9° 183	27.7	+ 9 18	9.1	10.10	.
10	+ 7° 107	42.0	+ 8 6	8.9	8.95	.	51	+10° 203	28.5	+10 24	8.2	8.03	.34
11	+ 7° 110	42.6	+ 7 59	9.5	. .	.	52	+ 9° 186	29.4	+ 9 42	9.5	11.15	.
12	+ 8° 110	43.0	+ 8 41	7.7	8.02	.00	53	+ 9° 187	30.0	+ 9 25	9.0	8.88	.
13	+ 7° 115	44.4	+ 7 49	9.3	9.74	.	54	+ 9° 188	30.2	+ 9 38	9.5	10.92	.
14	+ 7° 124	47.3	+ 8 8	8.5	8.70	.	55	+ 9° 191	32.0	+ 9 36	9.5	11.28	.
15	+ 9° 101	47.6	+ 9 16	8.3	8.44	.02	56	+ 9° 195	32.8	+10 8	9.3	9.92	*.05*
16	+ 7° 135	51.2	+ 7 47	8.8	9.42	.	57	+ 9° 196	32.9	+10 13	9.2	10.04	*.12*
17	+ 9° 110	51.6	+ 9 29	8.7	8.77	.01	58	+ 9° 199	33.3	+ 9 23	8.8	8.95	.
18	+ 7° 137	51.8	+ 7 55	9.5	11.77	.	59	+ 9° 200	33.9	+ 9 28	9.4	11.21	.
19	+ 7° 144	55.5	+ 8 10	9.1	9.79	.	60	+ 9° 201	34.2	+10 10	8.8	9.06	.11
20	+ 7° 145	55.8	+ 8 15	8.5	9.15	.	61	+ 9° 203	36.0	+ 9 37	9.0	9.17	.
21	+ 7° 147	56.1	+ 7 55	8.1	7.38	.	62	+ 9° 205	37.0	+ 9 40	9.5	11.00	.
22	+ 8° 152	56.2	+ 8 22	9.3	. .	.	63	+ 9° 206	37.3	+ 9 45	8.2	7.41	.04
23	+ 7° 148	56.3	+ 7 57	9.4	. .	.	64	+10° 234	39.3	+10 24	9.0	8.88	*.11*
24	+ 7° 150	56.7	+ 8 3	9.5	11.46	.	65	+10° 242	42.1	+10 28	9.0	9.04	.23
25	+ 7° 151	56.9	+ 7 24	8.0	7.68	.16	66	+ 9° 220	42.4	+ 9 56	9.5	10.55	.
26	+ 7° 154	58.1	+ 8 4	8.3	8.48	.	67	+ 9° 223	43.3	+ 9 43	8.7	8.69	.
27	+ 7° 157	58.7	+ 7 57	9.1	9.92	.	68	. . .	44.6	+ 9 58	. .	. .	.
28	+ 7° 166	1 1.2	+ 7 57	9.3	10.40	.	69	. . .	44.7	+10 5	. .	. .	.
29	+ 8° 173	1.4	+ 8 21	7.5	7.56	.14	70	+ 9° 234	47.7	+ 9 56	9.0	8.83	.
30	+ 7° 169	1.6	+ 8 7	8.2	8.02	*.32*	71	+ 9° 274	53.4	+10 9	9.1	9.63	.
31	+ 8° 179	4.0	+ 8 30	9.3	9.88	.	72	. . .	55.3	+10 25	. .	. .	.
32	+ 8° 180	4.6	+ 9 6	9.5	10.10	.	73	+10° 270	55.8	+10 21	9.0	8.79	.18
33	+ 8° 184	6.4	+ 8 33	9.3	10.62	.	74	. . .	56.4	+10 48	. .	. .	.
34	+ 8° 185	6.9	+ 8 25	9.2	9.66	.	75	+12° 292	2 4.4	+12 42	7.5	7.66	*.04*
35	+ 7° 185	7.4	+ 8 11	9.5	10.76	.	76	. . .	6.0	+11 25	. .	11.71	.
36	+ 8° 197	10.4	+ 8 14	8.5	8.16	*.02*	77	+10° 295	6.4	+10 51	9.5	10.77	.
37	+ 8° 202	11.9	+ 8 22	9.3	9.81	.	78	+10° 306	10.5	+10 54	8.2	8.22	.
38	+ 8° 204	12.8	+ 8 30	9.5	10.67	.	79	+11° 335	20.2	+11 32	7.3	7.50	.02
39	+ 8° 205	12.9	+ 8 24	9.5	10.55	.	80	+11° 337	20.6	+11 28	9.0	9.04	.
40	+ 8° 211	15.2	+ 8 38	8.5	9.10	*.11*	81	+11° 345	23.5	+11 33	8.0	8.17	.
41	+ 9° 158	17.5	+ 9 50	7.0	7.38	.09	82	. . .	3 10.6	+13 34	. .	12.44	.

No.	DM. No.	R.A. 1900.	Dec. 1900.	DM. Magn.	Photom. Magn.	Diff.	No.	DM. No.	R.A. 1900.	Dec. 1900.	DM. Magn.	Photom. Magn.	Diff.
		h. m.	° ′						h. m.	° ′			
83	. . .	3 11.2	+13 32	. .	12.01	.	95	. . .	3 56.0	+15 3	. .	. .	.
84	+14° 545	11.6	+15 2	9.0	8.78	*.04*	96	. . .	4 4.1	+15 23	. .	11.91	.
85	+13° 534	11.8	+13 31	9.5	10.59	.	97	+15° 590	4.2	+15 35	9.2	10.08	.
86	. . .	29.1	+14 21	. .	12.77	.	98	. . .	4.3	+15 24	. .	. .	.
87	. . .	29.3	+14 19	. .	12.80	.	99	+14° 661	5.0	+14 59	8.8	9.09	.00
88	+15° 535	43.2	+15 16	8.5	8.88	.01	100	+15° 607	11.2	+15 58	7.1	6.78	.06
89	. . .	46.5	+14 58	. .	12.39	.	101	. . .	11.3	+15 34	. .	. .	.
90	. . .	46.6	+14 45	. .	. .	.	102	+15° 609	12.6	+15 51	9.0	10.05	.
91	+14° 623	47.9	+14 48	9.5	10.32	.	103	. . .	12.8	+15 37	. .	. .	.
92	+15° 555	51.2	+15 14	8.4	8.72	.02	104	. . .	5 34.7	+16 48	. .	. .	.
93	+15° 565	55.1	+15 12	7.7	7.94	*.20*	105	. . .	34.8	+16 48	. .	. .	.
94	. . .	55.8	+15 0	. .	. .	.	106	. . .	6 8.7	+17 0	. .	. .	.

EDWARD C. PICKERING.

March 30, 1909.

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CIRCULAR 157.

BRIGHTNESS OF HALLEY'S COMET.

A careful series of measures of the nucleus of Halley's Comet was made by Professor O. C. Wendell with the photometer, with achromatic prisms, attached to the 15-inch Equatorial of this Observatory. The method of measurement was the same as that described in H.A. **69**, Part **1**. The results are contained in Table I, which gives in the first three columns the date, the Julian Day and decimal, and the designation of the comparison star in the Bonn Durchmusterung. The fourth column gives the measured difference in magnitude between the star and the Comet, each measure being the mean of four sets of four settings each. In every case the star was brighter than the Comet. The assumed photometric magnitude of the star, taken from the sixth column of Table I of H.C. 156, is given in the fifth column. When the star occurs in H.A. **54**, also, the mean of the two magnitudes was used. Adding the numbers in the last two columns gives the concluded magnitude of the nucleus, which is entered in the sixth column.

TABLE I.

BRIGHTNESS OF NUCLEUS.

Date.			Julian Day.	Comp. Star.	Diff.	Magn. Star.	Magn. Nucl.
y.	*m.*	*d.*	*d.*				
09	12	4	8645.631	+15° 609	2.56	10.05	12.61
	12	6	8647.596	+15° 590	2.38	10.08	12.46
	12	8	8649.545	+15° 565	4.55	7.84	12.39
	"	"	8649.567	. . .	4.64	. .	12.48
	12	9	8650.530	+15° 555	3.54	8.73	12.27
	"	"	8650.541	. . .	3.52	. .	12.25
	12	10	8651.545	+14° 623	2.28	10.32	12.60
	12	18	8659.561	+13° 534	2.14	10.59	12.73
	12	30	8671.549	+11° 345	4.20	8.17	12.37
	12	31	8672.534	+11° 337	3.36	9.04	12.40
y.	*m.*	*d.*	*d.*				
10	1	4	8676.543	+10° 295	1.41	10.77	12.18
	1	7	8679.653	+10° 270	3.21	8.88	12.09
	1	8	8680.535	+ 9° 247	2.82	9.63	12.45
	1	10	8682.562	+ 9° 234	3.44	8.83	12.27
	1	11	8683.585	+ 9° 223	3.91	8.69	12.60
	1	15	8687.542	+ 9° 199	3.31	8.95	12.26
	2	1	8704.573	+ 8° 173	3.98	7.63	11.61
	2	14	8717.526	+ 7° 124	2.30	8.70	11.00
	2	25	8728.522	+ 7° 89	0.68	9.33	10.01
	3	3	8734.515	+ 7° 83	1.30	7.96	9.26

It did not seem probable that direct estimates, by Argelander's method, of the entire light of the Comet would have much value, owing to the difficulty of comparing a large hazy object with a minute brilliant point of light like a star. A series of estimates, however, was undertaken by Mr. Leon Campbell, and the results are so accordant that similar estimates should be made if possible of other bright comets that may appear. In the later observations, the stars were thrown out of focus to render the comparison with the Comet easier. It should be remembered that Mr. Campbell has already acquired a fixed value of his estimate of a grade, derived from about twenty thousand observations during the last eight years. The results obtained from these estimates of the light of the Comet are given in Table II. The date, the Julian Day and decimal, and the comparison are given in the first three columns. The numbers designating the comparison stars are taken from the first column of Table I of H.C. 156. The intervals, expressed in grades, are printed in Italics. The deduced magnitude, assuming the value of a grade to be 0.10 magn., is given in the fourth column. Italics indicate that the magnitudes are uncertain, since, in these cases, the comparison stars cannot be measured photometrically until next year. The aperture of the instrument used is given in the fifth column, 6 denoting the 6-inch West Equatorial, and 24, the 24-inch Reflector.

TABLE II.

VISUAL ESTIMATES.

Date.			Julian Day.	Comparison.	Magn. Comet.	Inst.	Date.			Julian Day.	Comparison.	Magn. Comet.	Inst.
y.	*m.*	*d.*	*d.*				*y.*	*m.*	*d.*	*d.*			
09	10	17	8597.847	106 *5*	*14.1*	24	10	1	7	8679.517	74 *3, 2* 72	*11.4*	6
	11	9	8620.718	104 *5, 0* 105	*13.0*	24		1	11	8683.524	69 *3, 2* 68	*12.0*	24
	11	30	8641.576	R	11.5	24		1	26	8698.553	R	11.1	6
	12	4	8645.603	101 *4, 2* 103	*11.5*	24		2	4	8707.481	19 *5, 2* 22	10.29	6
	12	6	8647.594	96 *4, 2* 98	12.31	6		2	5	8708.533	23 *4, 2* 24	11.26	24
	12	8	8649.583	94 *2, 2* 95	*12.0*	6		2	14	8717.512	12 *3, 1* 11	10.04	24
	12	10	8651.582	89 *3, 2* 90	12.69	24		2	25	8728.500	7 *3, 0* 8	8.67	6
	12	14	8655.522	87 *3, 4* 86	12.74	6		3	3	8734.497	1 *5, 2* 2	7.79	6
	12	18	8659.633	83 *2, 4* 82	12.12	24		3	4	8735.506	1 *3, 3* 2	7.59	6
10	1	4	8676.517	77 *3, 0* 76	11.39	6		3	7	8738.498	1 *2, 5* 2	7.49	6

On November 30, the Comet was referred to the comparison stars of W Tauri, and on January 26, to those of S Piscium.

The letters P, V, and T, in Figure 1, indicate the brightness as derived photometrically, visually, and by theory, respectively. The theory here used is that the light is inversely as the square of the distances from the Sun and the Earth. This law will be true only if the light of the Comet is derived wholly from the Sun. The spectrum shows that this is not the case. The theoretical curve may be moved vertically, at will. If raised by about two squares it will fairly represent the observed values until the Comet apparently underwent an actual change due to the heat of the Sun. A difference, which is nearly constant, between the visual and photometric values might be expected owing to the different methods used.

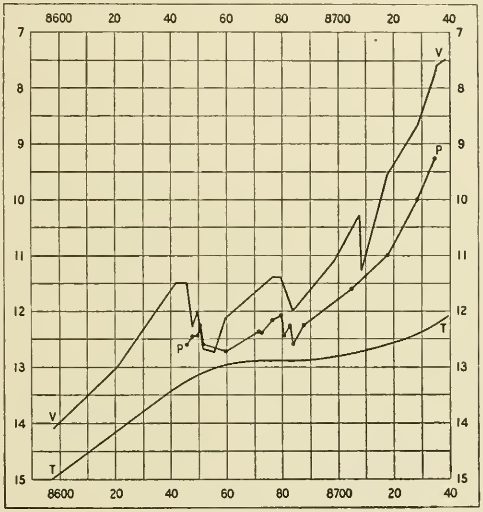

FIGURE 1.

EDWARD C. PICKERING.

MARCH 30, 1910.

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CIRCULAR 158.

STARS HAVING PECULIAR SPECTRA. 38 NEW VARIABLE STARS.

An examination of the photographs of the Henry Draper Memorial, by Mrs. Fleming, has led to the discovery of a number of variable stars and other objects having peculiar spectra, and the following description of them has been prepared by her.

A list of the variable stars is given in Table I. Two variable stars, *142760* and *210753*, found by Miss Mackie, and one, 190048, found by Miss Breslin, are included in this list. All of these variables have been confirmed independently by Miss L. D. Wells, and two of them, 124238 and 231040, were found independently by Miss Annie J. Cannon in her examination of the Harvard Map of the Sky. The star, 192745, was suspected of variability by Espin. The designation given in H.A. 55, the number, as assigned in the list of variables discovered at this Observatory, the constellation, and the Durchmusterung number are given in the first four columns. The designations for stars north of declination —23°, in 1855, are taken from the Bonn Durchmusterung. For stars between declinations —23° and —52° the Cordoba Durchmusterung, and for stars south of declination —52°, in 1875, the Cape Photographic Durchmusterung, is used. The approximate right ascension for 1900, and the approximate declination for 1900 are given in the fifth and sixth columns. The estimated magnitude, when brightest and when faintest, and the amount of change as derived from the plates used in confirming the variation are given in the seventh, eighth, and ninth columns. The class of spectrum from which, in general, the variable was discovered, the number of plates examined, and the first and last year covered by these plates are given in the tenth, eleventh, and twelfth columns.

Table II contains a list of stars having peculiar spectra. The Durchmusterung number, right ascension for 1900, declination for 1900, Durchmusterung magnitude, class of spectrum, and a brief description of the spectrum are given in the

TABLE I.

NEW VARIABLE STARS.

Design.	H.V.	Constellation.	DM.	R.A. 1900.	Dec. 1900.	Bright.	Faint.	Range.	Sp.	No. Plate.	Year.	
				h. m.	° ′							
002212	3229	Cetus	−12° 72	0 22.9	−12 12	6.0	7.0	1.0	Md	28	1899	1909
014453	3230	Perseus	+53° 398	1 44.0	+53 14	8.9	10.5	1.6	Mc	31	1892	1909
033380	3231	Cepheus	+79° 110	3 33.8	+80 0	7.7	9.0	1.3	Md	31	1892	1903
050238	3232	Auriga	+38° 1035	5 2.2	+38 52	9.0	10.6	1.6	N	26	1891	1905
052707	3233	Orion	+ 7° 929	5 27.8	+ 7 4	8.7	10.6	1.9	N	13	1889	1902
095659	3234	Carina	−59° 1591	9 56.7	−59 44	8.6	10.1	1.5	N	28	1893	1908
120950	3235	Centaurus	−50° 6814	12 9.3	−50 59	9.3	10.8	1.5	N	17	1891	1908
124238	3236	Can. Venat.	. . .	12 42.6	+38 55	8.0	<12.5	4.5+	Md	36	1892	1909
132824	3237	Hydra	−24° 10977	13 28.8	−24 53	8.1	9.6	1.5	Md	17	1896	1909
134244	3238	Centaurus	−43° 8554	13 42.7	−44 1	9.4	10.4	1.0	Mc 5	20	1890	1903
135230	3239	Centaurus	−30° 11047	13 52.0	−30 34	7.6	14.0	6.4	Md	13	1889	1908
*142760*b	3240	Centaurus	. . .	14 27.6	−60 33	10.8	13.3	2.5	. .	17	1893	1907
143532	3241	Bootes	+33° 2482	14 35.1	+32 58	8.2	10.0	1.8	Mc 5	21	1892	1909
143731	3242	Bootes	+32° 2504	14 37.0	+31 59	7.5	9.8	2.3	Mc 5	46	1892	1909
151675	3243	Apus	−75° 1158	15 16.1	−75 34	10.2	<11.8	1.6+	N?	17	1896	1909
163526	3244	Scorpius	−26° 11477	16 35.6	−26 55	8.8	9.8	1.0	Mc 5	27	1889	1908
164921	3245	Ophiuchus	−21° 4445	16 49.1	−21 48	8.4	9.6	1.2	Mc 5	26	1890	1909
170131	3246	Scorpius	. . .	17 1.1	−31 42	9.3	12.9	3.4	Md	17	1895	1907
170907	3247	Ophiuchus	− 7° 4412	17 9.6	− 7 57	9.5	11.5	2.0	. .	187	1899	1909
172049	3248	Ara	. . .	17 20.1	−49 49	10.7	<13.2	2.5+	Md?	21	1895	1908
173643	3249	Scorpius	−43° 11957	17 36.2	−43 43	11.1	12.8	1.7	Mc 5	12	1889	1909
175938	3250	Corona Aust.	. . .	17 59.0	−38 15	10.0	<12.3	2.3+	Md	14	1896	1908
183107	3251	Scutum	− 7° 4633	18 31.7	− 7 41	9.7	12.0	2.3	Na	22	1891	1905
183647	3252	Telescopium	−47° 12488	18 36.5	−47 21	9.6	10.8	1.2	Md?	30	1889	1908
184916	3253	Sagittarius	−16° 5074	18 49.1	−16 39	8.1	9.0	0.9	Mc 5	14	1891	1908
*190048*b	3254	Telescopium	−48° 12915	19 0.6	−48 24	9.3	14.9	5.6	Md	158	1899	1908
192662	3255	Pavo	−63° 4530	19 26.4	−62 58	8.7	10.4	1.7	Mc 5	20	1889	1907
192745	3256	Cygnus	+45° 2913	19 27.2	+45 57	7.3	9.0	1.7	Mc 5	23	1900	1908
194018	3257	Sagittarius	−18° 5480	19 40.6	−18 24	8.4	10.2	1.8	N	24	1889	1908
195763	3258	Pavo	. . .	19 57.7	−63 42	8.9	<12.2	3.3+	Md	14	1889	1908
202505	3259	Aquila	− 5° 5288	20 25.0	− 5 6	9.6	10.5	0.9	Mc 5	25	1809	1909
203551	3260	Indus	−51° 12676	20 35.1	−51 27	9.5	10.9	1.4	Md?	28	1889	1909
210753	3261	Indus	. . .	21 7.2	−53 26	8.6	11.0	2.4	Md	22	1891	1903
211642	3262	Microscop.	−42° 15413	21 16.6	−42 24	10.3	<13.5	3.2+	Md	20	1889	1907
212354	3263	Indus	. . .	21 23.4	−54 24	8.1	<11.9	3.8	Md	13	1894	1903
213753	3264	Indus	. . .	21 37.1	−53 11	9.5	12.9	3.4	Md	11	1893	1905
231040	3265	Andromeda	+40° 5026	23 10.0	+40 15	8.5	10.0	1.5	Md	45	1895	1909
234546	3266	Andromeda	+46° 4187	23 45.9	+46 57	7.2	8.7	1.5	Mc 5	20	1889	1906

successive columns of the Table. H.C. 143 contains a list of the stars having spectra of Class R, and a description of that class of spectrum. A few stars of this class are also given in H.C. 149. The galactic longitudes and latitudes of the objects having spectra of Classes O and P are given in the Remarks following Table II.

TABLE II.

PECULIAR SPECTRA.

DM.	R.A. 1900.		Dec. 1900.		Magn.	Spectrum.	Description.
	h.	m.	°	′			
. . .	4	11.8	+26	6	. .	R	Type VI.
+34° 1929	8	53.6	+34	9	8.9	R	Type VI.
−54° 3389	10	12.7	−55	5	8.6	O	Type V. Bright lines.
. . .	11	24.0	−52	23	. .	P	Bright lines. Gaseous Nebula.
−61° 2945	12	0.2	−61	30	9.6	O	Type V. Bright lines.
−50° 8073	13	44.6	−50	43	10.0	P	Bright lines. Gaseous Nebula.
. . .	15	54.2	−76	42	. .	R	Type VI.
−14° 4371	16	7.6	−14	57	9.5	R	Type VI.
−66° 2978	16	25.8	−66	55	8.7	R	Type VI.
. . .	16	29.6	−55	28	. .	P	Bright lines. Gaseous Nebula.
. . .	17	15.8	−43	43	. .	R	Type VI.
. . .	17	32.0	−44	6	. .	P	Bright lines. Gaseous Nebula.
−34° 12200	17	46.7	−34	42	7.5	Ap	$H\beta$ bright.
−26° 12879	18	4.1	−26	40	10.0	R	Type VI.
−14° 5265	18	56.9	−14	0	9.1	Ap	$H\beta$ bright.
−17° 5492	19	3.0	−17	26	9.6	R	Type VI.
−31° 16465	19	7.1	−31	7	9.7	R	Type VI.
. . .	19	44.1	+17	57	. .	O	Type V. Bright lines.
− 0° 3883	19	52.5	− 0	2	9.3	R	Type VI.

REMARKS.

h. m.

10 12.7. Galactic longitude, 249° 56′; galactic latitude, —1° 7′.

11 24.0. Galactic longitude, 258° 26′; galactic latitude, +7° 55′.

12 0.2. Galactic longitude, 265° 16′; galactic latitude, —0° 8′.

13 44.6. Galactic longitude, 280° 18′; galactic latitude, +10° 0′.

16 29.6. Galactic longitude, 298° 45′; galactic latitude, —6° 43′. Very faint object. Identification difficult.

17 32.0. Galactic longitude, 313° 56′; galactic latitude, —8° 8′.

h. m.

18 56.9. The bright line in the spectrum of this star, on A 8330, taken June 1, 1907, appears to be of slightly greater wavelength than $H\beta$, but it is not the line 5007, characteristic of gaseous nebulae. A slight trace of a bright line on the edge of greater wavelength of the dark line, $H\beta$, is visible in the spectrum of this star, on A 8350, taken June 7, 1907. The bright line may be variable in the spectrum of this star.

19 44.1. Galactic longitude, 23° 23′; galactic latitude, —5° 1′.

EDWARD C. PICKERING.

March 31, 1910.

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CIRCULAR 159.

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15 NEW VARIABLE STARS IN HARVARD MAP, Nos. 7, 10, 16, AND 19.

THE examination of photographs forming the map of the sky has been continued by Miss Cannon, and the description of the results described below has been prepared by her.

A summary of the results is given in Table I, in the same form as Table I of Circular 130. The successive columns give the number of the plate in the Map of the Sky, the approximate right ascension and declination of the centre, the number of new variables discovered, the total number found, the proportion which is new, the whole number known, the probable number, the proportion of the probable number which was actually found, the probable number unknown, and the probable proportion unknown.

TABLE I.

NUMBER AND DISTRIBUTION OF THE VARIABLES.

No.	Region.		New Variables.	Total Found.	Proportion New.	All.	Probable Number.	Proportion Found.	Probable No. Unknown.	Proportion Unknown.
	h.	°								
7	15	+60	4	9	.44	15	20	.45	5	.25
10	0	+30	1	14	.07	29	30	.47	1	.03
16	12	+30	4	8	.50	10	12	.67	2	.17
19	18	+30	6	11	.55	26	44	.25	18	.41

The following known variables were found. In H. M. 7, T Ursae Minoris, U Ursae Minoris, S Bootis, R Draconis, and 170764. In H. M. 10, 231040, W Pegasi, Z Andromedae, SU Pegasi. RS Andromedae, Z Pegasi, 235832, SV Andromedae, T Andromedae, SW Andromedae, R Andromedae, TU Andromedae, and RW Andromedae. In H. M. 16, RU Ursae Majoris, T Canum Venaticorum, 60 B Canum Venaticorum, and 124238. In H. M. 19, RS Herculis, SZ Herculis, 174916. T Herculis, W Lyrae, and 231040.

Table II contains a list of the new variable stars. The first column gives the designation according to the plan adopted in H.A. **55**. The second column gives the number in the order of discovery and announcement at this Observatory. The third, fourth, fifth, and sixth columns give, respectively, the constellation, the Durchmusterung number, the right ascension, and the declination for 1900. The seventh, eighth, ninth, tenth, and eleventh columns give the brightest and faintest photographic magnitudes yet observed, the range of the variation, the class to which the variable appears to belong, and the number of plates on which the star has been examined.

TABLE II.

NEW VARIABLE STARS.

Design.	H.V.	Constellation.	DM.	R.A. 1900.			Dec. 1900.		Bright.	Faint.	Range.	Class.	No. Plate.
				h.	m.	s	°	′					
000126	3267	Pegasus	+26° 4746	0	1	21.0	+26	30.3	9.6	10.5	0.9	IV?	25
115116	3268	Leo	+16° 2320	11	51	4.1	+16	18.3	8.9	9.7	0.8	. .	30
122727	3269	Coma Berenices	. . . .	12	27	47.8	+27	34.5	10.5	11.5	1.0	. .	15
123528	3270	Coma Bernices	. . . .	12	35	7.4	+28	2.6	10.2	11.1	0.9	IV?	20
131546	3271	Canes Venat.	+46° 1862	13	15	5.8	+46	3.2	8.5	9.4	0.9	. .	25
133674	3272	Ursa Minor	+75° 512	13	36	54	+74	49.0	9.0	9.9	0.9	IV?	44
144156	3273	Draco	+56° 1756	14	41	5.6	+56	32.2	9.8	10.6	0.8	. .	35
153264	3274	Draco	+64° 1077	15	32	23	+64	14.4	7.8	9.8	2.0	V	50
163360	3275	Draco	+60° 1688	16	33	36.4	+60	40.2	8.5	9.3	0.8	. .	42
171036	3276	Hercules	+36° 2843	17	10	52.7	+36	29.3	8.6	9.4	0.8	. .	30
171541	3277	Hercules	+42° 2823	17	15	26.8	+41	59.6	8.1	9.0	0.9	V	60
173120	3278	Hercules	+20° 3519	17	31	13.3	+20	45.7	9.1	9.8	0.7	. .	60
175030	3279	Hercules	. . . .	17	50	42.1	+30	25.8	9.5	11.0	1.5	. .	18
181031	3280	Hercules	. . . .	18	10	56.6	+31	47.3	10.5	<13	>2.5	II	40
181947	3281	Draco	+47° 2625	18	19	28.1	+47	30.7	9.0	9.6	0.6	. .	87

REMARKS.

123528. This is the south preceding component of a double star. At minimum, the variable becomes nearly as faint as the north following component.

153264. This star appears to be certainly of the Algol type. It is of normal brightness, magnitude 7.8, on 45 of the 50 photographs examined. The dates of the photographs on which it is faint, the Greenwich Mean Time of the middle of the exposure, and the estimated magnitudes are, on March 24, 1899, 20ʰ 53ᵐ, magn. 8.5, May 5, 1900, 16ʰ 54ᵐ, magn. 9.8, February 27, 1908, 21ʰ 23ᵐ, magn. 9.4, March 15, 1909, 14ʰ 24ᵐ, magn. 9.8, and April 19, 1909, 20ʰ 11ᵐ, magn. 9.5. The spectrum of this star is Class B 9. In H.A. **55**, 276, the declination of this star is given incorrectly as +64°33′, instead of +64° 14′.

171541. This star is of normal brightness, magnitude 8.1, on 58 photographs. On a photograph taken July 9, 1903, 19ʰ 38ᵐ, Greenwich Mean Time, the magnitude is 8.9 and on a photograph taken September 30, 1908, 13ʰ 54ᵐ, the magnitude is 9.0. The variation is apparently of the Algol type.

181031. This star is a variable of long period, but the preliminary examination of the photographs fails to determine the period, which does not, however, appear to be longer than 200 days.

181947. Owing to the small range of variation, this star was examined on a large number of photographs. The variable is at minimum on 10 of the 89 photographs examined. The period is either short or irregular.

THE VARIABLE STAR, 124045, +46° 1817.

While superposing the plates of Map 16, the star +46° 1817 which was called 60 Canum Venaticorum by Bode, was found to be considerably fainter on March 15, 1905, than on April 2, 1907. So far as known, this star is not included in any catalogue of variables. The Harvard card catalogue, containing references to all the published observations of variable stars, gives the following facts concerning this object.

In A.N. **82**, 126, Schmidt stated that, in August, 1872, he found this very red star, which was rated 5·6 magnitude by Argelander and Heis, to be scarcely equal to the sixth magnitude, that it slowly increased up to the middle of December, and was again near minimum on June 17, 1873. In A.N. **89**, 165, Schmidt again gave observations proving its variability, with dates of four maxima and four minima, occurring between 1873 and 1876, in a period which was very irregular, but which equalled approximately 386 days. Luizet later confirmed the variability, within the limits 5.2 to 6.0, by observations between 1898 and 1903. See A.N. **165**, 343.

In order to obtain further confirmation of the variability, and to gain some idea of the nature of the light curve, estimates of the brightness of this star were made on 154 photographs, taken with the Cooke lens, between March 12, 1899 and January 15, 1910. The method used for estimating these magnitudes was that proposed in H. C. 125. A sequence of comparison stars near the variable was marked on a plate which had also been exposed for an equal length of time on the Pole, and on which the standard sequence was therefore photographed. The magnitudes of the comparison stars were thus readily derived by direct comparisons with the standard sequence. These observations show that this star varies very irregularly. Maxima occurred about February 1, 1900, magn. 7.7, June 12, 1901, magn. 7.5, April 15, 1902, magn. 7.7, February 14, 1903, magn. 7.9, and June 1, 1906, magn. 7.5. Minima occurred about May 2, 1900, magn. 8.5, March 11, 1901, magn. 8.7, January 15, 1902, magn. 8.8, March 25, 1906, magn. 8.3. The spectrum of this star is Class N, or fourth type, and, owing to its color, the photographic values are at least two magnitudes fainter than the visual.

EDWARD C. PICKERING.

March 31, 1910.

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CIRCULAR 160.

PHOTOGRAPHIC MAGNITUDES. PROGRESS TO JULY, 1910.

THE scale which has been adopted as a standard here may be defined by three conditions. First, that if the intervals are equal, or in arithmetical progression, the intensities of the corresponding lights shall be in geometrical progression, thus according with the law of Fechner. Secondly, that, as in the case of visual magnitudes, the unit shall correspond to the light ratio, 2.512, whose logarithm is 0.400. This condition was proposed for visual magnitudes, by Pogson. It is precise only for stars of the same color, but is in universal use for photometric measures of visual magnitudes. The third condition is that the origin of the scale shall be such that the photographic and photometric magnitudes, on the Harvard scale, shall be the same for all stars whose spectrum is of the first type, or of Class A. This will include one half of the stars of all magnitudes, whose visual and photographic magnitudes will thus be the same.

Three methods have been found here to give satisfactory results in determining photographic magnitudes. The first of these depends on the law that the color of all stars, whose spectrum is of the same class, is the same. In H.A. 59, Nos. 4 and 5, Mr. King has shown that this law is correct, within the limits of errors of observation, for 33 and 76 bright stars, respectively. In H.A. 59, No. 6, he has confirmed this result for another set of 76 stars, by an improved method of observation. The constants found for each class of spectrum, to reduce the photometric to the photographic magnitudes, are as follows: —

B	A	F	G	K	M
– 0.31	0.00	+ 0.32	+ 0.71	+ 1.17	+ 1.68

Accordingly, if the visual magnitude of a star is 5.00, and its spectrum is Class A, the photographic magnitude will also be 5.00. If the spectrum is Class B, the photographic magnitude will be 5.00 – 0.31 = 4.69, and if of

Class M, it will be 5.00 +1.68 =6.68. The corrections for intermediate classes of spectra were also found, and are nearly the same as those given by direct interpolation. In H.A. 71, No. 1, similar values are found for the Oxford and Potsdam magnitudes, and it appears that the visual and photographic magnitudes on these scales will be the same for stars of Classes A1 and A8, respectively. The Revised Harvard Photometry gives the magnitudes and class of spectrum of 9110 stars, including nearly all of the magnitude 6.50, and brighter. The photographic magnitudes of all of these stars are thus readily obtained. From a comparison of the magnitudes of 78 stars measured in H.A. 59, 50, at Oxford, and at Potsdam, it appears that the average error in the photographic magnitudes derived in this way, is only ± 0.06, which includes the errors in H.A. 50, in classifying the spectra and in determining the photometric magnitudes. This is a very satisfactory result for the bright stars. It cannot be used for faint stars owing to the difficulty in classifying the spectra. An error of four tenths of a magnitude will occur if a star of Class K is wrongly classified as G or M. For faint stars, it is recommended that only stars of Class A be employed. While it is possible that there will be small differences for individual stars, this deviation appears to be beyond our present means of measurement. The discussion by Kapteyn, A.P.J. 30, 284, 398, indicates that the effect of the absorption of space, if any, is insensible. Should it ever be shown to be appreciable, it will only be necessary to assume as an origin of the scale the stars whose distance is not great.

The second method is that described in H.C. 125, and adopted by the International Chart Conference of 1909. Two exposures of equal length are made on the same plate, one on the North Pole, the other on the stars to be measured when both regions are at the same altitude. These photographs must be taken only on the very best nights when the sky appears to be equally clear in both regions. A sequence of stars near the North Pole is then selected and their photographic magnitudes determined with the greatest possible care. The photographic magnitude of all northern stars can thus be found by direct inspection. For extreme southern stars, a second sequence of stars near the South Pole is required. Some of the methods and the resulting magnitudes of the stars in the northern sequence are described in H.C. 150. Since then, the work on the faintest stars has been greatly extended by photographs taken with the 24-inch Reflector of the Yerkes Observatory, the 60-inch Reflector of the Mt. Wilson Solar Observatory, and the 16-inch Metcalf

Doublet. The second of these instruments, with exposures of four hours, has permitted the sequence to be extended so as to include stars of about the twentieth magnitude. It is hoped that definitive magnitudes can be found shortly for all of these stars. It is deemed best not to publish provisional magnitudes, lest these might be used instead of the final values. The greater portion of the work on the North Polar Sequence has been done by Miss Leavitt. 11 instruments have been used, having apertures from half an inch to sixty inches. About eleven thousand measures have been made of two hundred photographs. The method of duplicate exposures is likely to be especially useful for stars from the sixth to the fourteenth magnitude, which can be photographed with exposures of about ten minutes. If long exposures are made, the haziness of the sky may change, and serious errors may enter if the images do not have the same form in the two exposures. The very faint stars of the Polar Sequence, however, will have great value as standards of magnitude, and as tests of any new method of determining absolute magnitudes. Several hundred photographs have been taken here, at Arequipa, and at the South African Station of this Observatory, by this method. Sequences have been selected in the fifty regions which for many years have been used as standards here. These consist of the North Pole, the South Pole, and the centres of the 48 regions of equal area, each about 30° square, into which the entire sky has been divided. In each of the 36 northern regions, in declinations +75°, +45°, +15°, and −15°, the photographic magnitudes of 27 stars have been measured, on three plates each, by Miss Leland. This catalogue of 972 stars is nearly ready for publication. Different plates of the same region show small systematic errors, which have an average value of ±0.09. When these are eliminated, the average deviation for a single star is ±0.10. One of these sequences can be substituted for the Polar Sequence at observatories near the Equator, where the Pole is low, or when it is desired to observe regions nearer together, or at a greater altitude. The visual magnitudes of 15 of these stars in each region have been measured by the writer with the 12-inch Meridian Photometer. Sequences have been selected for the 12 southern regions and for the South Pole, and have been measured photometrically by Professor Bailey, in South Africa. Photographs have been taken there connecting these regions with the South Pole, and in Arequipa, connecting them with the regions at +15°. The whole will thus be brought into one system, both photographically, and photometrically. This method is not to be recommended for very faint stars, for which long exposures are required. Owing to the second exposure, the entire exposure of the plate is doubled, so that the fogging by the light of the sky is increased, and it is difficult to insure uniform transparency of the air during the entire period. Of special importance is a series of photographs taken with Anastigmat lenses, each covering two regions 30° square. They will cover the whole sky, and furnish the means of obtaining by inspection the photographic magnitude of any star of the twelfth magnitude, or brighter. Before they can be used, however, a large piece of work must be completed in determining the magnitudes of 32 sequences, north of declination +75°, with which they may be compared. This is essential, owing to the great variation in scale in different parts of the plate, the effect of atmospheric absorption, and other sources of error.

The third method of determining photographic magnitudes is that described in H.A. 26, page xiv. A small circular prism of very small angle is attached to the centre of the objective of the photographic telescope. A nearly constant proportion of the light of each star will be diverted, and form an image at a distance from the principal image rather more than half the angle of the prism. If the diameter of the small prism is one tenth of that of the large telescope, about one hundredth of the light will be diverted, and the secondary images will be about five magnitudes fainter than the principal images. Accordingly, every tenth magnitude star will be accompanied by an image equal to that of a star of the fifteenth magnitude. Although this method has been employed here for more than twenty years, yet it is only recently that good results have been obtained with it. Among the sources of error may be mentioned the reduction in aperture due to diffraction, the unequal absorption of the centre and edges of the large lens, its chromatic aberration, the effect of dust on different parts of the lens, the different appearance of the two sets of images, and many others. Some of these sources of error require that a different constant shall be used for stars of different magnitudes and on different nights. If then the constant must be determined empirically, this method loses its principal advantage, and may not be better than that of taking two exposures having different duration. It has long been known that the photographic effect is not proportional to the time of exposure, but depends on so many other quantities that absolute magnitudes cannot be determined directly in this way. If, however, the difference between the magnitudes of the bright and faint images has to be determined empirically in both cases, it may be a difficult matter to decide which method is preferable. Among the advantages of the two exposures may be mentioned, that the images will resemble each other more closely, change of focus and dust or dirt on the objective will have no effect. With the auxiliary prism, passing clouds or varying haze will have no effect, and the auxiliary images over a much larger portion of the plate can be compared with the principal image of the faint stars. A comparison of the results, in practice, is now being made here.

The relative advantages of the three methods may now be compared. The first method, by means of the spectrum, leaves little to be desired in the case of the bright stars. A connection is made with the well established system of photometric magnitudes. The class of spectrum is already published for stars as bright as the magnitude 6.5, and can probably be furnished, from the Harvard collection of photographs, for other stars to the eighth magnitude, or fainter.

The second method, by duplicate exposures, appears to be the best for stars from the seventh to the fourteenth magnitude. The errors although sensible are not very serious, and may be reduced indefinitely by additional photographs. If the method of covering large regions proves successful, we shall have the material for determining the light of all the stars in the sky, of the twelfth magnitude and brighter, on a few plates, and their errors can then be determined and a correction applied in each case. The third method, using an auxiliary prism or a second exposure, appears to be the best for very faint stars, from the twelfth to the twentieth magnitude. It may be combined with the first method, at least in the case of doublets. The small expense of an auxiliary prism will probably permit the magnitudes of the faintest stars to be determined on the absolute scale.

Numerous other methods have been tried here for reducing the brightness of the photographic images by a known amount, for instance, shade glass, photographic films, reduced apertures, wire gauze, perforated sheet-metal, and polarized light. These methods appear to be more valuable for determining standards, than for general use for large numbers of stars.

It will be seen that the whole problem is a very large and difficult one, and that, although a great amount of time and work has already been devoted to it here, much remains to be done, and the complete solution cannot be expected for some time.

One of the most serious difficulties encountered in determining photographic magnitudes is that dependent on the distance from the centre of the plate, of stars of different brightness. For stars about three magnitudes brighter than the faintest stars shown on the photograph, the effect is comparatively small. As we recede from the centre, bright stars appear brighter, and faint stars fainter, owing to the increased size of the images. The difference may amount to a whole magnitude for an ordinary lens, at the corners of a square 2° on a side. Even in the case of a doublet, the same error may appear at the corners of a region 5° square. In the case of a reflector whose focal length is five times the aperture the effect is perceptible at a distance of 7′ from the centre, and probably has the value given above, at the corners of a square 25′ on a side. Another very troublesome source of error is the effect of change of focus, especially in the case of a reflector. Two exposures, ninety minutes apart, were made of the same region. Owing to change of focus, the bright stars were half a magnitude brighter, and the faint stars half a magnitude fainter, in the first exposure than in the second.

EDWARD C. PICKERING.

AUGUST 1, 1910.

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CIRCULAR 161.

CURVED PHOTOGRAPHIC PLATES.

THE focal surface of a single lens, for parallel rays of light, is not a plane, but is roughly represented by a spherical surface whose concavity is turned towards the lens, and whose centre is midway between the lens and its focus. This was demonstrated, both theoretically and experimentally, in 1875, in a paper by the writer, published in the Proc. Amer. Acad. 10, 300. The field covered by the lenses of a photographic telescope could be greatly extended by the use of concave plates. The problem was discussed at length, at the first meeting of the International Chart Conference, in 1887. Many difficulties presented themselves. It was thought that the photographic plates must be ground to the required curvature, and that the emulsion would not adhere as well to such a surface as to one of pressed glass. The sensitive emulsion would collect at the centre of a curved plate, thus forming a film thicker than at the edges. It was proposed to remedy this difficulty by rotating the plate, so that the centrifugal force might overcome the force of gravity. It was expected that difficulty would be experienced in storing curved plates, and that if turned over they might break each other. Such plates have not come into general use, although it is understood that it is usual for makers to coat the concave side of plates which are not flat.

In the careful study, now being made here, of the 16-inch Metcalf Telescope, it appears that, by varying the focus, excellent images can be obtained in turn, in every part of an 8×10 plate which covers a region 5° square. The lens is a Petzval doublet, having a focal distance about seven times the aperture. The scale of the photograph, therefore, is about $90'' = 1$ mm. The difference in focus of the edges and centre of the plate is only about 0.8 mm., so that it seemed probable that an ordinary plate could be bent by this amount without breaking. Various methods were proposed for bending the plate, such as placing a concave surface behind the plate and exhausting the air; attaching a wet leather disk, which would adhere by atmospheric pressure, and drawing the centre of the plate back, by means of a cord; placing a convex lens over the plate and bending the edges of the plate against it; bending the plate by a metallic point placed in front of it, which would, however, cast a shadow and cut off the stars in the centre of the plate; placing a plano-concave lens in front of the plate, and in contact with it, which would shorten the focus by an amount equal to about one third of the thickness of the portion of the lens traversed by the light, and therefore more at the edges than at the centre.

A partial solution of this problem was found by placing a concave metal surface behind the plate, adding a few drops of water or glycerine, and pressing the plate down in the centre. By capillarity, the plate adheres to the surface behind it. The constant pressure on the edge of the liquid film, as the glass tends to recover its form, causes the film to contract gradually, and after a time separation takes place. Fairly good results were obtained with an adhesive liquid, like mucilage. The first method mentioned above, exhausting the air back of the plate, gave much more satisfactory results. To render the joint between the plate and the holder air-tight, a gasket composed of glue and glycerine, like a printer's roller, was employed.

The results obtained with curved plates are shown in the accompanying figures, which are enlargements of the centre and of the edge of Plate MC 450, taken with the 16-inch Metcalf Telescope, on June 29, 1910. Two exposures were made, of ten minutes each, the first and left hand images being taken with the plate curved; the second, detaching the plate so that it was flat. Figure 1 shows a region near the centre of the plate, R.A. $18^h\ 59^m.4$, Dec. +4° 47′ (1855), enlarged about nine times, to a scale of $10'' = 1$ mm. The three brightest stars are +4° 3976, magn. 8.9, +4° 3975, magn. 9.1, and +4° 3973, magn. 9.3. It will be seen that the two images of each star are equally good, as of course they should be, if properly focused. Figure 2 shows a region 2° 41′ south of this, whose centre is R.A. $18^h\ 59^m.4$, Dec. +2° 6′ (1855). The only catalogue star in the region shown is +2° 3788, magn. 9.5. It will be seen that the left hand images, taken when the plate was curved, are nearly as good as in Figure 1, while the images when the plate was flat are much poorer, especially for the faint stars.

It now becomes a question how far bending the plate will affect the determination of magnitudes and positions. It is shown, in H.C. 160, that magnitudes are seriously affected by the distance from the centre of the plates. Two plates were taken, MC 456 and MC 457, having four exposures

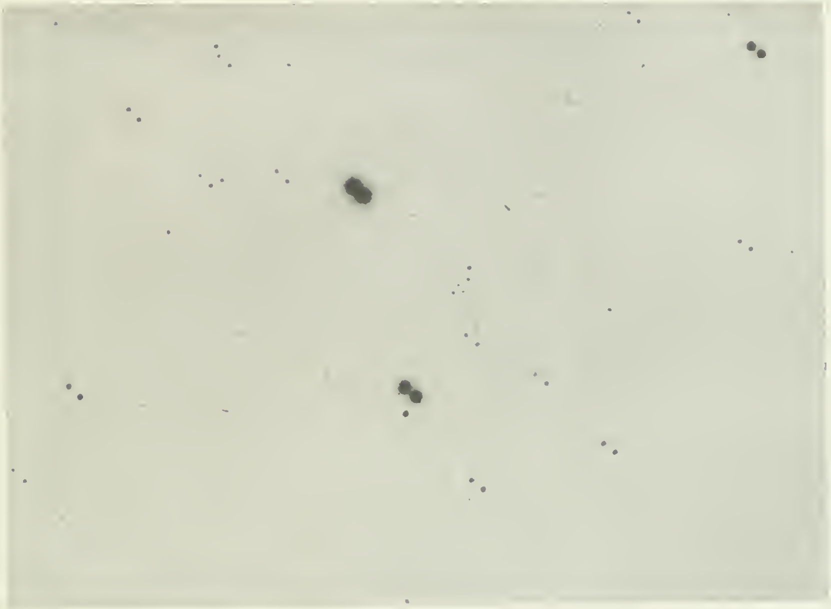

Fig. 1, Centre.

Fig. 2, Edge.

of 10^m each, in declinations $+90°.0$, $+89°.2$, $+88°.4$, and $+87°.6$, respectively. Measures were made, by Miss Leavitt, of the four images thus obtained, of 61 stars fainter than the tenth magnitude. The first plate indicates that the images 1°.5 from the centre show a decrease in brightness, of 0.17 magn. On the other plate, however, the images in the same part of the plate show an increase in brightness of 0.06 magn. With this exception, there is no evidence of systematic error, exceeding a tenth of a magnitude.

The effect on the positions of the stars, due to curving the plates, can only be determined by actual measures. It appears probable, however, that it will increase, rather than diminish, the accuracy. The errors introduced will be radial, and the correction will no longer be proportional to the tangent of this distance. It will be a question whether the plates should be flat or curved, when measured. If curved, it will be a great advantage that the curvature in all the plates will be the same, instead of differing as in ordinary plates. The focus of the microscope of the micrometer will vary, but this may be corrected easily by the use of curved guides, or by a source of light which will form a very small emergent pencil. The actual lateral deviation, due to curving the plate, will ordinarily be so small as to be negligible.

EDWARD C. PICKERING.

August 1, 1910.

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CIRCULAR 162.

22 NEW VARIABLE STARS IN HARVARD MAP, No. 52.

In continuation of the search for new variable stars, Map No. 52 has been studied by Miss Cannon, who has prepared the following statement of the results of her examination. Table I gives a summary of the results, in the same form as Table I of H.C. 159. The successive columns give the number of the plate in the Map of the Sky, the approximate right ascension and declination of the centre, the number of new variables discovered, the total number found, the proportion which is new, the whole number known, the probable number, the proportion of the probable number which was actually found, the probable number unknown, and the probable proportion unknown.

TABLE I.

NUMBER AND DISTRIBUTION OF THE VARIABLES.

No.	Region.		New Variables.	Total Found.	Proportion New.	All.	Probable Number.	Proportion Found.	Probable No. Unknown.	Proportion Unknown.
	h.	°								
52	18	−60	22	35	.63	62	108	.57	46	.43

The following known variables were found, S Trianguli Australis, *162855*, *163059*, R Arae, *164360*, *164565*, V Pavonis, U Arae, W Arae, S Arae, R Pavonis, *181146*, and S Pavonis.

Table II contains a list of the new variable stars. The first column gives the designation according to the plan adopted in H.A. 55. The second column gives the number in the order of discovery and announcement at this Observatory. The third, fourth, fifth, and sixth columns give, respectively, the constellation, the Durchmusterung number, the right ascension and the declination for 1900. The seventh, eighth, ninth, tenth, and eleventh columns give, respectively, the brightest and faintest photographic magnitudes yet observed, the range of the variation, the class to which the variable appears to belong, and the number of plates on which the star has been examined.

TABLE II.

NEW VARIABLE STARS.

Desig.	H. V.	Constellation.	DM.	R. A. 1900.	Dec. 1900.	Bright.	Faint.	Range.	Class.	No. Plates.
				h. m. s.	° ′					
160962	3282	Triang. Aust.	−62° 5265	16 9 24.0	−62 29.3	9.4	10.3	0.9	V?	22
161361	3283	Triang. Aust.	. .	16 13 11.7	−61 12.7	10.1	<11.5	>1.4	II	14
161559	3284	Norma	−59° 6719	16 15 49.2	−59 6.8	10.0	11.0	1.0	. .	12
162562	3285	Triang. Aust.	−62° 5377	16 25 18.5	−62 55.4	9.1	10.1	1.0	. .	12
163355	3286	Ara	−55° 7643	16 33 13.5	−55 6.2	8.9	9.6	0.7	. .	46
164964	3287	Ara	. .	16 49 26.7	−64 16.9	10.5	<14	>3.5	II	34
165857	3288	Ara	−57° 8290	16 58 1.8	−57 34.2	9.5	10.3	0.8	. .	44
171351	3289	Ara	−50° 11196	17 13 15.2	−51 1.4	8.9	10.3	1.4	. .	10
171855	3290	Ara	−55° 8112	17 18 3.0	−55 8.6	9.6	<12	>2.4	II	18
172060	3291	Ara	−60° 6831	17 20 1.8	−60 48.9	9.0	12.5	3.5	II	16
172364	3292	Ara	. .	17 23 17.0	−64 12.3	9.0	<13.0	>4.0	II	15
172657	3293	Ara	−57° 8613	17 26 17.4	−57 4.6	7.6	10.6	3.0	V	58
173660	3294	Pavo	−60° 6924	17 36 3.1	−60 27.9	8.5	9.3	0.8	. .	28
174863	3295	Pavo	−63° 4194	17 48 22.6	−63 37.0	8.0	8.7	0.7	. .	30
175552	3296	Ara	. .	17 55 1.2	−52 43.2	10.4	11.2	0.8	IV?	20
175858	3297	Pavo	. .	17 58 32.0	−58 58.2	9.6	10.8	1.2	IV?	12
180477	3298	Octans	−77° 1292	18 4 56.9	−77 42.4	9.4	10.0	0.6	. .	19
181143	3299	Corona Aust.	−43° 12429	18 11 35.0	−43 23.5	9.4	10.1	0.7	V?	37
182569	3300	Pavo	−69° 2912	18 25 18.8	−69 59.2	8.7	9.8	1.1	. .	21
183551	3301	Telescopium	−51° 11728	18 35 43.7	−51 43.4	9.0	10.2	1.2	V	31
183645	3302	Telescopium	−45° 12699	18 35 59.5	−45 52.6	9.0	10.2	1.2	II	22
185946	3303	Telescopium	−46° 12809	18 59 37.7	−46 7.1	8.9	9.9	1.0	. .	11

REMARKS.

160962. This star is of normal brightness, magnitude 9.4, on 18 of the 22 photographs examined. The dates of the photographs on which it is faint, the Greenwich Mean Time of the middle of the exposure, and the estimated magnitudes are, on May 14, 1894, $17^h 36^m$, magnitude 10.0, April 2, 1898, $19^h 10^m$, magnitude 9.9, April 21, 1906, $19^h 54^m$, magnitude 9.9, June 23, 1909, $15^h 13^m$, magnitude 10.3. The spectrum of this star is of the first type, and probably of Class B 8. The variation appears to be of the Algol type.

164964. This is the south preceding component of a close double star. At minimum it becomes much fainter than the north following component, which is probably of about the twelfth magnitude. On a Bruce plate, taken June 23, 1897, the variable is invisible and fainter than the magnitude 14. A maximum occurred near the date, May 20, 1899. The period appears to be long.

171855. This star has a faint companion of the approximate magnitude 12, which follows about $0^m.1$, and is slightly north. The variable at minimum becomes fainter than the companion. The period is probably long.

172657. This is a variable of the Algol type. It is of the approximate magnitude 7.6, on 55 of the 58 plates which were examined. The dates of the photographs on which it is faint, the Greenwich Mean Time of the middle of the exposure, and the estimated magnitudes are, on May 31, 1894, $19^h\ 2^m$, magnitude 9.2, June 21, 1904, $14^h\ 44^m$, magnitude 9.2, July 1, 1907, $10^h\ 22^m$, magnitude 10.6. This variable is interesting on account of its large range. The spectrum is of Class B 8.

181143. This star is fainter than its normal brightness, magnitude 9.4, on 5 of the 37 plates examined. The dates on which it is faint, the Greenwich Mean Time of the middle of the exposure, and the estimated magnitudes are, on July 3, 1905, $16^h\ 42^m$, magnitude 10.0, April 18, 1907, $19^h\ 8^m$, magnitude 10.0, April 20, 1907, $20^h\ 54^m$, magnitude 9.6, June 1, 1907, $17^h\ 4^m$, magnitude 10.1, July 22, 1908, $13^h\ 34^m$, magnitude 10.1. Two plates were taken on June 1, 1907. On the first one, referred to above, the star is in minimum light, but on the other one, taken two hours and six minutes later, the magnitude is 9.5, which is near normal brightness. The spectrum of this star is Class B 5. The variation is probably of the Algol type.

183551. This star appears to be an Algol variable. It is faint on 2 of the 31 plates examined. At maximum, its magnitude is 9.0. On July 18, 1901, $16^h\ 31^m$, its magnitude was estimated 10.2, and on July 5, 1904, $14^h\ 38^m$, it was estimated as 9.8. The spectrum is classified B 8. It is of the later helium type, which is common to a large number of variables of the Algol type.

183645. This variable was found on March 11, 1910. On August 2, 1910, it was found independently by Mrs. Fleming, by means of its spectrum, which she classified as Md on a plate taken September 30, 1909.

EDWARD C. PICKERING.

SEPTEMBER 21, 1910.

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CIRCULAR 163.

181325. NOVA SAGITTARII, No. 3. H. V. 3306.

THIS new star was discovered by Miss Cannon, who has prepared the following statement of the results of her observations.

Nova Sagittarii, No. 3, was found while examining a plate taken at Arequipa on September 6, 1899, with the 1-inch Cooke Lens. As is customary with the writer, when a new variable star is found, a number of photographs taken in different years were examined to determine something of the character of the variation. The peculiar nature of the light curve was soon evident. An examination was therefore made of a large number of photographs taken between June 7, 1889 and September 3, 1910. The object is visible on 27 photographs taken with six different telescopes, between August 10, 1899 and October 3, 1901. It is not seen on 112 other photographs, including three in 1889, one in 1890, two in 1891, five in 1893, nine in 1895, eight in 1896, three in 1897, two in 1898, fifteen in 1902, eight in 1903, ten in 1904, seven in 1905, eight in 1906, nine in 1907, eight in 1908, seven in 1909, and seven in 1910.

The position of the Nova was measured on a plate taken with the Bruce Telescope on April 30, 1900, when the light had decreased to the magnitude 12. The position thus found for 1900 is R.A. $= 18^h\ 13^m\ 47^s.5$, Dec. $= -25°\ 13'.5$. It is in nearly the same right ascension as C.DM. $-25°$ 13020, magn. 10, and about 1′ north. This Durchmusterung star may be seen as a rather faint object on the Map of the Sky, No. 43, in the position [77, 151].

Table I gives a list of the observations of the Nova. The first column gives the plate number, in which the letter A represents plates taken with the 24-inch Bruce Telescope; X, those with the 13-inch Boyden Telescope; B, with the 8-inch Bache Telescope; I, with the 8-inch Draper Telescope; AC and AM, with the 1-inch Cooke lenses, in Cambridge and Arequipa, respectively. The second, third, and fourth columns give the date, the length of the exposure, and the Julian Day after subtracting 2,410,000. The last column gives the estimated magnitudes on the absolute scale.

TABLE I.

OBSERVATIONS OF NOVA SAGITTARII, No. 3.

Plate.	Date.			Ex.	J. D.	Magn.	Plate.	Date.			Ex.	J. D.	Magn.
	y.	m.	d.	m.				y.	m.	d.	m.		
A 3807	99	8	3	35	4870	R	A 4340	00	4	30	122	5140	12.0
AM 68	99	8	5	62	4872	< 9.5	B 25197	00	5	1	60	5141	12.0
AC 377	99	8	6	64	4873	<10.5	B 25345	00	5	18	10	5158	12.0
AM 75	99	8	7	62	4874	<10.6	B 25390	00	5	22	10	5162	12.0
AM 87	99	8	9	76	4876	<11.4	B 25746	00	7	21	79	5222	12.0
X 9918	99	8	10	100	4877	8.5	B 25879	00	9	1	10	5264	12.2
AM 104	99	8	23	60	4890	8.6	B 26116	00	9	13	10	5276	12.3
AM 116	99	8	25	70	4892	8.8	B 26387	00	10	11	11	5304	12.3
AM 137	99	9	6	75	4904	9.4	B 26461	00	10	22	51	5315	R
AM 204	99	10	11	62	4939	R	B 26472	00	10	23	49	5316	12.2
B 24376	99	10	13	11	4941	10.5	B 26473	00	10	23	45	5316	12.2
I 24710	00	3	7	10	5086	11.5	B 26483	00	10	24	45	5317	12.2
I 25099	00	4	8	62	5118	11.9	B 26491	00	10	25	45	5318	12.2
A 4293	00	4	10	120	5120	12.0	B 27408	01	5	25	10	5530	12.7
A 4297	00	4	11	120	5121	11.8	B 28160	01	8	7	88	5604	13.1
A 4331	00	4	26	125	5136	12.0	B 28621	01	10	3	11	5661	13.3

REMARKS.

A 3807. On seven photographs taken August 3, 1899, with the Bruce Telescope, for the cluster N.G.C. 6266, a faint star appears, which is within the errors of measurement of the position of the Nova. Its magnitude is 15.6, and no variation has been found on five Bruce plates taken before the new star appeared, and on five similar plates taken since 1905.

AM 204. Nova seen, but images distorted, and no estimate made.

B 26461. Nova seen, but plate so poor that magnitude has not been estimated.

Although no spectrum of this star was obtained, the suddenness of the outburst, and the form of the light curve, leave no doubt as to the character of the object. The star is not visible on photographs taken August 5, 6, 7, and 9, 1899. On the plate taken August 9, 1899, G.M.T. $14^h\ 24^m$, an adjacent star of magnitude 11.4 is present, but there is no trace of the Nova. The plate taken the next evening, August 10, 1899, G.M.T. $12^h\ 28^m$, shows the new star at full brightness. On August 23, the magnitude was about the same, and it appears probable that it may have been brighter during the interval

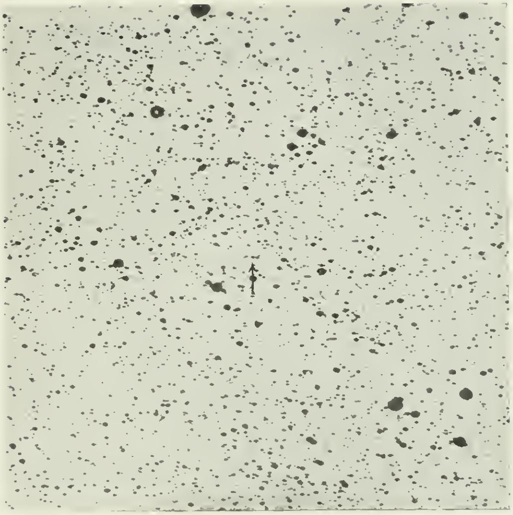

FIG. 1. AUG. 3, 1899.

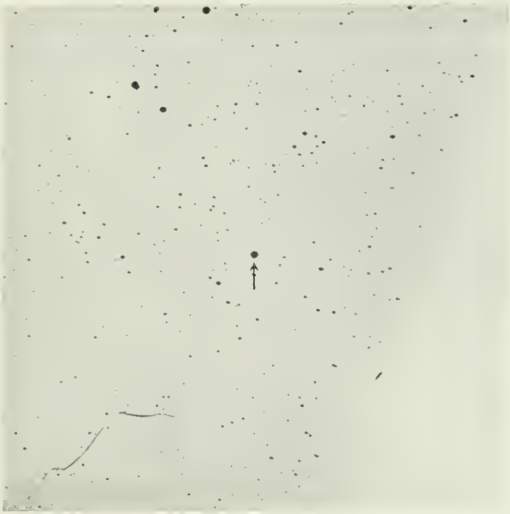

FIG. 2. AUG. 10, 1899.

NOVA SAGITTARII. No. 3.

between August 10 and August 23. The light faded rapidly at first, but was nearly stationary and of magnitude 12.0 from April to July, 1900. It then decreased slowly, and was magnitude 13.3 on October 3, 1901. Since that time, it has not been seen, unless we assume that the faint object on the Bruce plates is identical with the Nova. These variations are represented graphically in Figure 3.

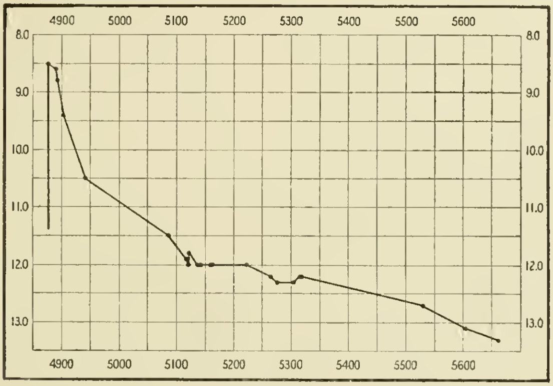

FIGURE 3.

A photograph of the vicinity of the Nova, taken with the Bruce Telescope on August 3, 1899, is shown in Figure 1. Scale 20″ = 0.1 cm. The same region, taken with the Boyden Telescope on August 10, 1899, is shown in Figure 2. The object whose position is [24, 75] is a defect in printing. On the photograph taken August 9, 1899, the region is very near the edge of the field, and the images are considered too badly distorted for reproduction.

EDWARD C. PICKERING.

JANUARY 19, 1911.

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CIRCULAR 164.

NOVA SAGITTARII, No. 4. FIVE NEW VARIABLE STARS.

The examination of photographs forming the Map of the Sky has been continued by Miss Cannon, who has prepared the following statement of her recent results.

A rapid comparison of various photographs of the Map of the Sky, for the purpose of detecting new stars, has resulted in the discovery of Nova Sagittarii, No. 4, two new variable stars in Map 43, and three new variable stars in other regions. These are all given in Table I, in which the successive columns give the designation, the H.V. number, the constellation, the Durchmusterung number, the right ascension for 1900, the declination for 1900, the brightest and faintest photographic magnitude yet observed, the range of the variation, the class to which the variable appears to belong, and the number of plates on which the star has been examined.

TABLE I.

NEW VARIABLE STARS.

Desig.	H. V.	Constellation.	DM.	R. A. 1900.	Dec. 1900.	Bright.	Faint.	Range.	Class.	No. Plates.
				h. m. s.	° ′					
002050	3307	Cassiopeia	+50° 72	0 20 56.3	+50 43.6	7.2	8.6	1.4	IV	46
061033	3308	Auriga	+33° 1290	6 10 40.2	+33 14.6	9.6	10.3	0.7	. .	45
073017	3309	Gemini	. .	7 30 16.2	+17 7.8	9.6	10.4	0.8	V	30
165926	3310	Ophiuchus	−26° 11880	16 59 53.7	−26 26.8	7.2	8.0	0.8	IV	17
175217	3311	Sagittarius	−17° 4978	17 52 56.4	−17 23.6	9.0	10.6	1.6	V	89
180027	3312	Sagittarius	. .	18 0 27.3	−27 26.5	10.4	<16	>5.6	I	153

REMARKS.

002050. The period appears to be short. The spectrum is of Class G.

061033. The period may be irregular. The spectrum is of Class Mc.

073017. In normal light, this star is brighter photographically than +17° 1620, magn. 9.3, or +17° 1620a, magn. 9.5. At minimum, it becomes fainter than either. It is fainter than its normal brightness on

5 of 30 photographs examined. The times of the middle of the exposures of the plates on which it is faint, expressed in Julian Days and decimals following Greenwich Mean Noon, are, 2415317.927, 2416905.622, 2419044.780, 2419089.596, and 2419089.638. The spectrum is of Class A, and the variation is probably of the Algol type.

165926. The period appears to be short. The spectrum is of Class G.

175217. This star is fainter than its normal magnitude on 7 of 89 photographs examined. The times of the middle of the exposures of the plates on which it is faint, expressed in Julian Days and decimals following Greenwich Mean Noon, and the approximate magnitudes, are, 2416319.544, magn. 10.4, 2418467.714, magn. 10.4, 2418499.711, magn. 9.7, 2418514.621, magn. 10.3, 2418531.563, magn. 9.8, 2418531.608, invisible and fainter than 10.5, and 2418878.635, magn. 10.6. The spectrum is of Class A. This star appears to be an Algol variable, whose period is short.

180027. Nova Sagittarii, No. 4. This object appears on eleven photographs taken between May 22 and July 9, 1901. No trace of it is found on 148 other photographs, of which one was taken in 1892, six in 1893, one in 1895, four in 1896, three in 1897, seven in 1898, eleven in 1899, fifteen in 1900, eight in 1901, nine in 1902, thirteen in 1903, fifteen in 1904, fifteen in 1905, seven in 1906, six in 1907, twelve in 1908, ten in 1909, and five in 1910. All of these photographs show the star C. DM. −27° 12411, magn. 9.7, which may be seen on the Map of the Sky, No. 43, [95,139]. The new star at maximum equalled the photographic magnitude of this Durchmusterung star. Six photographs, taken with the Bruce 24-inch Telescope, in 1897, 1898, 1900 and 1907, show no trace of a star in the position of the new star. A star of the approximate magnitude 14, in nearly the same right ascension, south 0′.3 appears on all the photographs which show faint stars.

Table II gives a list of the observations of Nova Sagittarii, No. 4. The first column gives the number of the plate, in which AM represents plates taken with the 1-inch Cooke lens, and B, those taken with the 8-inch Bache Telescope. The second, third, fourth, and fifth columns give, respectively, the calendar date, the length of the exposure, the Julian Day, after subtracting 2,410,000, and the magnitude estimated on the absolute scale.

The exact date of the appearance of this object cannot be fixed. It is visible at its greatest observed brightness on May 22, 1901, but is not seen on a photograph taken April 10, 1901, which shows the adjacent star of magnitude 14, slightly south of the position of the Nova. The fluctuations in brightness appear to be somewhat similar to those of Nova Persei, No. 2, during its so-called oscillatory period, from March to June, 1901.

TABLE II.

OBSERVATIONS OF NOVA SAGITTARII, No. 4.

Plate.	Date.			Ex.	J. D.	Magn.	Plate.	Date.			Ex.	J. D.	Magn.
	y.	*m.*	*d.*	*m.*				*y.*	*m.*	*d.*	*m.*		
AC 1462	01	5	13	55	5518	<10.4	AM 835	01	6	6	63	5542	R
AM 802	"	5	22	60	5527	10.3	AM 841	"	6	7	61	5543	11.7
B 27408	"	5	25	10	5530	11.8	AM 854	"	6	14	525	5550	R
AM 808	"	5	27	51	5532	10.5	AM 855	"	6	15	569	5551	10.3
B 27438	"	5	27	10	5532	10.4	B 27750	"	6	25	10	5561	11.9
AM 817	"	5	28	60	5533	10.4	AM 907	"	7	9	60	5575	11.7

REMARKS.

B 27408. The star is on the edge of the plate, but appears to be certainly much fainter than on May 22, or on May 27.

AM 835. Nova certainly seen, but so near the edge of the plate that the image is too distorted to estimate.

AM 841. Image poor. Estimate uncertain.

AM 854. A multiple image plate. The Nova is seen, but, owing to superposition of images of adjacent stars, no estimate was made.

AM 855. A multiple image plate. The star is certainly much brighter than on AM 841, taken June 7.

It is of interest to note that seven new stars are known to have appeared in the region covered by No. 43 of the Harvard Map of the Sky. The first was Nova Ophiuchi, No. 1, *172421*, Kepler's new star of 1604, which rivalled Venus in brilliancy. Nova Ophiuchi, No. 2, *165312*, appeared in 1848, and Nova Sagittarii, No. 1, *185613*, in 1898, both of these being on the extreme edge of Map 43. Nova Sagittarii, No. 3, *181325*, appeared in 1899, Nova Sagittarii, No. 4, *180027*, in 1901, Nova Scorpii, No. 2, *174734* b, in 1906, and Nova Sagittarii, No. 2, *175427*, in 1910.

EDWARD C. PICKERING.

March 18, 1911.

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CIRCULAR 165.

THREE NEW VARIABLE STARS IN HARVARD MAP, No. 22.

In continuation of the search for new variable stars, Map No. 22 has been examined by Miss Cannon, who has prepared the following statement of the results of her examination.

A summary of the results of the examination of H.M. 22 is given in Table I, in the same form as Table I of H.C. 162.

TABLE I.

NUMBER AND DISTRIBUTION OF THE VARIABLES.

No.	Region.		New Variables.	Total Found.	Proportion New.	All.	Probable Number.	Proportion Found.	Probable No. Unknown.	Proportion Unknown.
	h	°								
22	0	0	3	8	.38	17	22	.36	5	.23

The known variables, R Pegasi, S Pegasi, R Aquarii, U Pegasi, and S Ceti, were found, and also the minor planet Nausikaa, on photographs taken September 2 and September 14, 1903. The date of opposition given in the Berliner Jahrbuch is September 10, 1903.

The new variable stars may be found in Table II, in which the successive columns give the designation, the H.V. number, the constellation, the Durchmusterung number, the right ascension for 1900, the declination for 1900, the brightest and faintest photographic magnitude yet observed, the range of the variation, the class to which the variable appears to belong, and the number of plates on which the star has been examined.

TABLE II.

NEW VARIABLE STARS.

Desig.	H. V.	Constellation.	DM.	R. A. 1900.	Dec. 1900.	Brigbt.	Faint.	Range.	Class.	No. Plates.
				h. m. s.	° ′					
000519	3313	Cetus	−19° 7	0 5 52.0	−19 7.7	8.9	9.5	0.6	. .	38
232413	3314	Pegasus	+12° 4997	23 24 53.5	+12 59.6	9.4	<10.6	>1.2	V?	18
232907	3315	Pegasus	+ 7° 5056	23 29 19.6	+ 7 21.9	9.0	12.0	3.0	V	379

REMARKS.

000519. This star was at or near minimum on December 22, 1902, November 9, 1903, December 15, 1903, and August 22, 1905. The period may be irregular. The spectrum is of Class Mb.

232413. This star is fainter than normal on 4 of 18 photographs examined. The spectrum is of class B 9 or A, and the variation is, therefore, suspected to be of the Algol type.

232907. Near the border of Pisces. This star was found to be missing on AC 11980. An examination was therefore made of a large number of photographs to determine the nature and period of the variation. The variation is of the Algol type, and the range is unusually large for stars of this class. It is fainter than normal on 24 of 379 photographs. The spectrum is of Class A.

The estimated magnitudes of 232907 on the 24 photographs on which it is faint are given in Table III. The first column gives the number of the plate, in which AM and AC represent plates taken with the 1-inch Cooke lenses in Arequipa and Cambridge, respectively; B, those taken with the 8-inch Bache

TABLE III.

OBSERVATIONS OF THE ALGOL VARIABLE 232907 NEAR MINIMUM.

Plate.	Date.			J. D.	Magn.	E.	Phase.	Res.
	y.	*m.*	*d.*					
AM 83	99	8	8	4875.742	10.8	1294	*.066*	0
B 24117	99	9	11	4909.724	12.5	1303	.024	R
AM 289	99	11	18	4977.576	10.2	1321	.091	*1*
AM 668	00	9	19	5282.596	10.4	1402	.079	*1*
AC 4066	03	10	20	6408.535	<11.0	1701	.038	. .
B 34042	04	6	9	6641.901	10.6	1763	*.077*	0
B 34551	04	8	1	6694.765	10.3	1777	.066	*6*
AC 5681	04	12	7	6822.584	9.4	1811	*.153*	0
AM 3866	05	9	8	7097.675	11.4	1884	.033	*2*
AC 7753	06	8	28	7451.629	<11.4	1978	.000	. .
AC 7962	06	11	4	7519.570	9.2	1996	.156	*1*
AC 8085	06	12	4	7549.532	<11.1	2004	*.008*	. .
AM 5118	07	9	1	7820.754	10.4	2076	.075	*2*
AM 5185	07	10	5	7854.535	<10.8	2085	*.037*	. .
"		"		" .554	<11.0	"	*.018*	. .
"		"		" .575	<11.0	"	.003	. .
"		"		" .596	<11.0	"	.024	. .
"		"		" .617	R	"	.045	. .
AM 5185	07	10	5	7854.638	10.9	2085	.066	0
"		"		" .658	10.4	"	.086	0
"		"		" .680	10.0	"	.108	0
"		"		" .701	9.6	"	.129	*1*
"		"		" .721	9.4	"	.149	0
"		"		" .742	9.2	"	.170	0
"		"		" .763	9.1	"	.191	0
AC 8974	07	11	8	7888.579	10.0	2094	.115	1
AM 5571	08	6	17	8110.825	9.2	2153	.178	0
AM 6724	09	10	31	8611.634	10.0	2286	.132	3
AM 6769	09	11	11	8622.626	9.2	2289	*.173*	0
AC 11052	09	11	15	8626.639	10.4	2290	.074	*2*
AC 11098	09	11	30	8641.547	10.4	2294	*.081*	0
AC 11099	09	11	30	8641.589	11.1	"	*.039*	*2*
AC 11979	10	10	1	8946.649	< 9.8	2375	*.010*	. .
AC 11980	10	10	1	8946.691	<10.6	"	.032	. .
MC 792	10	12	8	9014.528	10.6	2393	.084	1

REMARKS.

B 24117. The star is fainter than on any other plate so far examined. The estimate appears to be too faint for the form of the light curve derived from the other observations. This may be due to a difference in scale for faint stars photographed by different instruments.

AM 5185. A multiple image plate, containing 12 exposures, of 30 minutes each. There is no trace of the first four images of this star. The fifth image is perhaps barely seen, but appears to be defective.

Telescope, and MC, with the 16-inch Metcalf Telescope. The second column gives the calendar date, the third, the time of the middle of the exposure, expressed in Julian Days and decimals following Greenwich Mean Noon, and corrected for the equation of light. The fourth column gives the estimated magnitude on the absolute scale. The fifth column gives the number of the period following J.D. 2,410,000, and the sixth, the phase, assuming the formula for times of minimum, J.D. $2,410,002.837+3^d.76582$ E. The seventh column gives the residuals from the assumed light curve, expressed in tenths of a magnitude.

As a test of the assumed formula, phases were computed for 61 photographs when the light of the star was recorded as normal, and none came within the computed times of the light changes, according to the formula.

Table IV gives the comparison stars employed. The successive columns give the designation, the Durchmusterung number, the right ascension for 1900, the declination for 1900, and the adopted photographic magnitude. These magnitudes were estimated by direct comparison with the polar sequence which had been photographed on the same plate, as explained in H.C. 125. For those stars not contained in the Durchmusterung, the positions were obtained by laying upon the photograph a glass plate ruled in squares, one millimetre on a side, and reading the coordinates of each star from a centre near the variable. The observed differences in right ascension and declination were added directly to the position of the variable.

TABLE IV.

COMPARISON STARS.

Desig.	DM.	R. A. 1900.		Dec. 1900.		Photog. Magn.	Desig.	DM.	R. A. 1900.		Dec. 1900.		Photog. Magn.
		h.	m.	°	′				h.	m.	°	′	
a	5180	23	34.3	+6	31.4	8.2	h	. .	23	31.1	+7	16.8	10.5
b	*5166*		25.9	+7	10.7	9.0	k	. .		30.8	+7	7.4	10.8
c	5045		27.6	+7	34.7	9.1	l	. .		30.2	+7	28.7	11.1
d	5053		29.1	+7	25.3	9.5	m	. .		30.3	+7	12.7	11.3
e	5050		28.8	+7	28.0	9.8	n	. .		29.3	+7	24.1	11.6
f	5052		29.5	+7	16.6	10.1	o	. .		30.8	+7	14.6	12.0
g	5173		28.3	+6	50.0	10.2	p	. .		29.3	+7	27.7	12.6

An ephemeris for this variable is given in Table V. It contains the predicted times of minimum, from July 1, 1911, to January 1, 1912, computed by the formula. J.D. 2,410,002.837+3^d.76582 E. The successive columns give the number of the period following J.D. 2,410,000, the Julian Day and decimal for the time of minimum, the corresponding month, day, and Greenwich Mean Time.

TABLE V.

EPHEMERIS OF MINIMA.

Epoch.	J. D.	G. M. T. 1911.				Epoch.	J. D.	G. M. T. 1911.				Epoch.	J. D.	G. M. T. 1911.			
			d.	*h.*	*m.*				*d.*	*h.*	*m.*				*d.*	*h.*	*m.*
2448	9221.564	July	3	13	32	2465	9285.583	Sept.	5	14	00	2481	9345.836	Nov.	4	20	4
2449	9225.330	"	7	7	55	2466	9289.349	"	9	8	22	2482	9349.602	"	8	14	27
2450	9229.096	"	11	2	18	2467	9293.115	"	13	2	46	2483	9353.368	"	12	8	50
2451	9232.862	"	14	20	42	2468	9296.881	"	16	21	9	2484	9357.134	"	16	3	13
2452	9236.628	"	18	15	4	2469	9300.647	"	20	15	31	2485	9360.900	"	19	21	36
2453	9240.393	"	22	9	26	2470	9304.412	"	24	9	54	2486	9364.666	"	23	15	59
2454	9244.159	"	26	3	49	2471	9308.178	"	28	4	17	2487	9368.431	"	27	10	21
2455	9247.925	"	29	22	12	2472	9311.944	Oct.	1	22	40	2488	9372.197	Dec.	1	4	44
2456	9251.691	Aug.	2	16	35	2473	9315.710	"	5	17	3	2489	9375.963	"	4	23	7
2457	9255.457	"	6	10	58	2474	9319.476	"	9	11	26	2490	9379.729	"	8	17	30
2458	9259.223	"	10	5	21	2475	9323.242	"	13	5	49	2491	9383.495	"	12	11	53
2459	9262.988	"	13	23	43	2476	9327.007	"	17	0	10	2492	9387.260	"	16	6	15
2460	9266.754	"	17	18	6	2477	9330.773	"	20	18	33	2493	9391.026	"	20	0	38
2461	9270.520	"	21	12	29	2478	9334.539	"	24	12	56	2494	9394.792	"	23	19	1
2462	9274.286	"	25	6	52	2479	9338.305	"	28	7	19	2495	9398.558	"	27	13	24
2463	9278.052	"	29	1	15	2480	9342.071	Nov.	1	1	42	2496	9402.324	"	31	7	47
2464	9281.817	Sept.	1	19	36												

EDWARD C. PICKERING.

APRIL 10, 1911.

AUG 16 1911
UNIVERSITY OF TORONTO

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 166.

COOPERATION IN OBSERVING VARIABLE STARS.

THE method of observing variable stars in use at this Observatory is described in H.C. 112. Of the 372 variables of long period, included in Table I which, in general, have a range of at least three magnitudes and are of the magnitude 9.0, or brighter, at maximum, 257 are north of declination −20°. Nearly all of the latter have been observed at least once a month, except when too near the Sun. During the years 1906 to 1910, about seventeen thousand observations have been made by astronomers connected with this Observatory, of which twelve thousand have been made by Mr. Leon Campbell. Six thousand observations have been kindly communicated by other astronomers. Also, a very large number of observations have been obtained by the members of the Variable Star Section of the British Astronomical Association, and by many individual observers. To avoid unnecessary duplication and to secure the best results, some form of cooperation seems advisable. In the past, comparatively few observations have been secured of the southern variables, and accordingly Mr. Campbell has gone to Arequipa to undertake their observation. His observing list will include all such stars south of the Equator, and all those between the Equator and declination +30° which are between 12^h and 24^h in right ascension, with the exception of a few stars which are now followed by two, or more, observers. Many of these stars are likely to be neglected, and the aid of other astronomers in observing them is earnestly requested.

Table I gives the designation of the variable in hours and minutes of right ascension, and degrees of declination, southern stars being indicated by Italics, the name of the variable, the maximum and minimum magnitude and the period, taken from H.A. 55, Table I or VII. The sixth column gives the letters designating the observers, so far as known, who are planning to undertake its observation. A indicates the observers at Amherst College

Observatory, principally Professor David Todd and Mr. C. J. Hudson; B, the observers of the British Astronomical Association; C, Mr. Leon Campbell, Arequipa, Peru; E, Mr. J. H. Eadie, Bayonne, N. J.; H, Mr. S. C. Hunter, New Rochelle, N. Y.; J, Mr. M. W. Jacobs, Jr., Harrisburg, Pa.; M, Mr. S. Manning, South Australia; O, Mr. W. T. Olcott, Norwich, Conn.; S, Miss H. M. Swartz, South Norwalk, Conn.; V, the observers of Vassar College Observatory, Poughkeepsie, N. Y., principally Dr. C. E. Furness and Miss P. R. Sutton; Y, Professor Anne S. Young, Mt. Holyoke College, South Hadley, Mass. Italics indicate that the stars are now being observed regularly, and therefore presumably these observations will be continued; Roman letters, that similar observations will be made at least once a month, except when too near the Sun.

While it is often possible to determine the form of light curve from observations made once a month, much more frequent observations are desired, especially in the case of stars whose periods are short. Accordingly, a large number of the variables have been assigned to two or more observers. Past experience has shown that, owing to clouds, moonlight, and other causes, it will be difficult even then to avoid intervals exceeding a month. On the other hand, there appears to be a needless duplication in the case of certain variables, and it is hoped that this may be avoided by correspondence between the observers. Certain stars of special interest have been assigned to all. This is also desirable for purposes of comparison. It is hoped the observers will find that they can follow many more stars than those assigned to them, as it is not probable that more observations will be secured for a large portion of the stars, than will be needed to determine the light curves in each case. Observations of the stars in the east, late at night or early in the morning, will have special value in diminishing the interval when the star is too near the Sun for observation. For similar reasons, observers having large telescopes could do very useful work by observing stars when too faint to be seen with small telescopes.

For several years, the approximate magnitudes of variables of long period have been published each month in Popular Astronomy. To continue this work, it is necessary that astronomers should send to the Harvard Observatory on the first of each month, a copy of their observations giving for each star, the name or designation, the date, and the concluded magnitude. Forms will be furnished for this purpose, and charts will be given to observers of the regions of such variables as they will observe systematically. These charts are paper prints, eight by ten inches in size, enlarged from photographs, to a scale of 20″ = 1 mm. for the fainter variables, and to a scale of 60″ = 1 mm. for the brighter variables. For many of the latter, the enlargements are made from the charts of the Bonn Durchmusterung. On some of the photographs, the image of each bright star is accompanied by a faint one, produced by a small prism placed in front of the objective, for photometric purposes.

The observations sent us will be printed in the Annals of the Observatory, if desired by the observers, as has been done in H.A. 37 and 57, unless provision has been made for their publication elsewhere. The results for 1906 to 1910 are now nearly ready for publication, and it is expected that a similar publication will be made of the results for 1911 to 1916.

TABLE I.

LIST OF VARIABLES.

Design.	Name.	Max.	Min.	Period.	Observer.	Design.	Name.	Max.	Min.	Period.	Observer.
000339	V Sculptoris	*9.0*	*12.0*	295	C	012350	RZ Persei	8.5	13.8	362	A
001032	S Sculptoris	*6.6*	*12.8*	366	C*M*	012502	R Piscium	7.6	13.5	344.15	OSY
001046	X Andromedae	8.0	<12	347	A*V*	013238	RU Andromedae	9.2	<13	243	AJ
001726	T Andromedae	8.0	14.5	281	OSY	013338	Y Andromedae	8.3	13	217.9	AJ
001755	T Cassiopeiae	6.9	12.3	445	B*SVY*	014958	X Cassiopeiae	9.0	12.3	409	BY
001838	R Andromedae	6.0	14.9	410.7	B*V*	015354	U Persei	7.5	11.0	320	B*V*
001862	S Tucanae	*8.7*	<*11.3*	240	C	021024	R Arietis	7.5	13.7	186.55	B*OV*
001909	S Ceti	7.9	14.5	320.2	C	021143a	W Andromedae	6.5	14.0	395	B*V*
*002438*a	T Sculptoris	7.8	11.4	201.5	C	021281	Z Cephei	9.5	<14.5	285	*A*
*002438*b	RR Sculptoris	9.0	11.5	. .	C	*021403*	*o* Ceti	1.7	9.6	331.6	B*O*
002546	T Phoenicis	*8.5*	<*12.0*	280	C	*022000*	R Ceti	7.8	14.0	167	C
002833	W Sculptoris	*8*	<*11*	. .	C	022150	RR Persei	*9*	<*13*	374	AY
003179	Y Cephei	9	12	332.7	HV	*022426*	R Fornacis	8.5	11.8	386	C
004047	U Cassiopeiae	8.0	16	276	SVY	*022813*	U Ceti	7.1	12.8	235.8	C
004132	RW Andromedae	*8.3*	<*12*	435	JO	022980	RR Cephei	*9.0*	<*13*	. .	AB
004435	V Andromedae	8.4	14.3	263	EHO	023133	R Trianguli	6.5	12.0	267	B*VY*
004435	X Sculptoris	9	<13	250	C	024356	W Persei	7.5	11.5	Irr.	EH
004533	RR Andromedae	8	<13	340	EHO	*025050*	R Horologii	*5.9*	*12.0*	405	C*M*
004746	RV Cassiopeiae	*9.0*	*12.5*	. .	AB	030514	U Arietis	7.0	13.0	370	Y
004958	W Cassiopeiae	8.3	12.1	404	J*V*	*031401*	X Ceti	8.0	13.0	176.5	*A*C
005475	U Tucanae	*9.1*	*13.0*	258	C	032335	R Persei	8.0	13.5	210.1	SVY
010102	Z Ceti	*9.0*	*13.0*	185	C	*034625*	U Eridani	8.5	<11.4	239	C
010630	U Sculptoris	9.0	<13 ?	328	C	*035124*	T Eridani	7.4	11.8	252	C
010940	U Andromedae	8.9	14.5	356	AB	*040725*	W Eridani	*8.1*	<*12.5*	374	C
011041	– Andromedae	*8.0*	*13.0*	. .	AB	042209	R Tauri	8.0	14.0	325	B*V*
011208	S Piscium	8.2	<14.7	404.3	OY	042215	W Tauri	8.0	12.2	Irr.	OY
011272	S Cassiopeiae	7.6	14.5	609.5	B*V*	042309	S Tauri	9.5	14.6	365	B*V*
*012233*a	R Sculptoris	6.2	8.8	376.4	C	043065	T Camelopard.	7.0	13.5	370	B*VY*
*012233*b	RS Sculptoris	9.8	11.0	. .	C	043208	RX Tauri	9.0	<12	. .	AB

Design.	Name.	Max.	Min.	Period.	Observer.	Design.	Name.	Max.	Min.	Period.	Observer.
043263	R Reticuli	7	12	273.4	C*M*	073723	S Geminorum	8.2	14.5	294	V
043274	X Camelopard.	8.0	13	140	E*O*Y	*074241*	W Puppis	*8.7*	*12.6*	120.8	C
043562	R Doradus	4.8	6.8	345	C	074323	T Geminorum	8.1	<13.5	288.1	B*V*
043738	R Caeli	*7.2*	*14.0*	398	C*M*	074922	U Geminorum	8.9	14	86.3	All
044349	R Pictoris	*7.6*	*10.0*	165	C*M*	081112	R Cancri	6.0	11.3	362	B*O*
044617	V Tauri	8.3	13.6	170.1	V	081617	V Cancri	7.5	13.0	272.1	EO
045307	R Orionis	8.7	13.5	378.5	Y	*082476*	R Chamaeleontis	*8.9*	*12.8*	335	C
045514	R Leporis	6.1	9.7	436.1	C	083019	U Cancri	8.4	<14	305.0	V
050003	V Orionis	8.4	<14.5	267	VY	083350	X Ursae Majoris	8.4	<13.0	247	B
050022	T Leporis	8.2	12.0	366.5	C	084803	S Hydrae	7.5	13.0	256	*E*HO
050848	S Pictoris	*8.7*	*<13.9*	428.5	C	*085008*	T Hydrae	7.0	13.1	288.8	C*O*
050953	R Aurigae	6.5	13.8	458.6	B*VY*	*090024*	S Pyxidis	8.2	<12.0	208	C
051247	T Pictoris	*8.4*	*12.4*	200	C	090425	W Cancri	*9.1*	*<13.5*	385	SV
051533	T Columbae	*7.5*	*11.8*	225	C	*091868*	RW Carinae	*8.5*	*<11.5*	322	C
052034	S Aurigae	9.0	11.2	Irr.	BY	*092551*	Y Velorum	8.6	12.5	437	C
052036	W Aurigae	8.7	15.0	276	OV	*092962*	R Carinae	4.5	10.0	309.3	C*M*
052404	S Orionis	8.0	14.3	413	C*V*	093178	Y Draconis	8.5	13	330	BY
*053005*a	T Orionis	9.0	13.0	Irr.	C	093934	R Leonis Minoris	7.0	13.0	370.5	B*HOS*
053068	S Camelopard.	8.0	10.0	328	B*VY*	*094023*	RR Hydrae	8.4	<13.0	336.8	C
053531	U Aurigae	8.0	13.5	405.5	Y	094211	R Leonis	4.6	10.5	312.8	B*EJOSVY*
054319	SU Tauri	*10.0*	*<15*	..	ABY	*094262*	l Carinae	3.6	5.0	35.5+	C
054331	S Columbae	9.0	<12.0	325.5	C	*094953*	Z Velorum	8.8	12.5	407	C
054615a	Z Tauri	9.0	<13	516	A	095421	V Leonis	8.6	<13.5	273.1	V
054629	R Columbae	*8.0*	*12.5*	323	C	*095458*	RR Carinae	*8.2*	*9.6*	Irr.	C
054920	U Orionis	5.5	12.5	375	B*H*	*095563*	RV Carinae	9.4	<13	370	C
054974	V Camelopard.	*8.0*	*<14*	272	*O*V	*100537*	R Antliae	7.2	7.8	..	C
055353	Z Aurigae	9	<12	112	Y	*100661*	S Carinae	5.8	9.0	148.7	C*M*
055686	R Octantis	*7.3*	*12.2*	408	C	*101153*	W Velorum	8.2	<12.0	390.5	C
060450	X Aurigae	8.2	13	161	B	*103270*	RZ Carinae	*9.0*	*<13.2*	272	C
060547	SS Aurigae	9.0	<14.5	Irr.	AVY	103769	R Ursae Majoris	7.0	13.5	302.1	B*EJOSVY*
061647	V Aurigae	9.0	11.7	352	V	*104620*	V Hydrae	7	10.0	Irr.	C
061702	V Monocerotis	7.2	<12.9	332	*A*C	*104628*	RS Hydrae	8.6	12.0	338	C
063159	U Lyncis	9.0	<12	R	A	104814	W Leonis	9	<14	388	VY
063558	S Lyncis	9.4	14	300	A	*110361*	RS Carinae	*8*	*<14*	..	C
064030	X Geminorum	8	13	262	BV	110506	S Leonis	9.0	13.5	189.5	Y
064707	W Monocerotis	8.8	<13	262.5	C	*111661*	RS Centauri	*9.2*	*<12.9*	166	C
065111	Y Monocerotis	8.0	13.5	225	BV	*114441*	X Centauri	*7.3*	*13.0*	313.9	C
065208	X Monocerotis	8.0	10.0	Irr.	C	*115058*	W Centauri	*8.6*	*13.1*	203	C
065355	R Lyncis	7.0	13.8	379.2	B*JY*	115919	R Comae Beren.	8.0	15.0	361.8	OV
070109	V Canis Minoris	8.8	<15	364	AV	120012	SU Virginis	*8.5*	*12.5*	..	C
070122a	R Geminorum	6.4	13.8	370.2	B*HV*	*120905*	T Virginis	8.7	13.5	339.5	C
070772	R Volantis	8.7	11.5	421	C	*121418*	R Corvi	7.5	12.6	318.5	CH*O*
071044	L² Puppis	3.4	6.2	140.15	C*M*	122001	SS Virginis	*8.3*	*12.5*	..	C
071201	RR Monocerotis	9.3	<15	392	*A*	122532	T Canum Venat.	8.6	12	290	VY
071713	V Geminorum	8.0	14.5	276	V	*122803*	Y Virginis	8.6	14.5	218.8	C*V*
072708	S Canis Minoris	7.0	12.2	330.3	EOS*V*	*122854*	U Centauri	*8.7*	*12.6*	219	C
072811	T Canis Minoris	9.1	<13.5	319	V	123160	T Ursae Majoris	6.4	13.1	257.2	B*EOSVY*
*072820*b	Z Puppis	7.5	13	524	C	123307	R Virginis	6.4	12.1	145.47	CH*O*
073173	S Volantis	9.1	<13	393.5	C	123459	RS Ursae Majoris	9.2	14.5	259	B*EV*
073508	U Canis Minoris	8.5	13.5	410	OY	123961	S Ursae Majoris	7.3	12.5	226.5	B*EOSVY*

Design.	Name.	Max.	Min.	Period.	Observer.
124204	RU Virginis	8	12	438	C
124606	U Virginis	7.5	13.5	206.92	*OSV*
131283	U Octantis	7.8	12.2	300.9	C
132202	V Virginis	8.0	14.0	250.5	C
132422	R Hydrae	4.0	9.8	425	*B*C
132706	S Virginis	5.6	12.3	376.9	*B*C
133155	RV Centauri	*9.0*	*<12.6*	. .	C
133273	T Ursae Minoris	8.5	<13	314	BV
133633	T Centauri	*6.5*	*9.2*	90.3	C
134236	RT Centauri	7.9	<11.5	248	C
134440	R Canum Venat.	6.1	12.7	326	B*SV*
134536	RX Centauri	8.6	<12.5	329	C
134677	T Apodis	8.1	<12.0	269	C
140113	Z Bootis	8.3	<13	284	C
140959	R Centauri	5.3	13	568.2	C*M*
141567	U Ursae Minoris	*8.5*	*12*	327	EJS*V*
141954	S Bootis	8.0	13.5	270	B*V*
142205	RS Virginis	*8.1*	*<12.3*	355	C
142539	V Bootis	6.9	11.0	259	B*SV*
142584	R Camelopard.	7.9	13.7	269.5	B*EJOSV*
143227	R Bootis	6.6	12.9	223.3	*BOS*
143417	V Librae	9.3	13.3	255.2	C
*144646*a	S Lupi	*9.6*	*14.2*	347	C
144918	U Bootis	9.1	13.6	177.5	C*V*
145971	S Apodis	*9.0*	*<11.3*	355 ?	C
150018	RT Librae	8.5	13.5	255	C
150605	Y Librae	8.2	12	277	CH
151520	S Librae	7.6	<13	192.1	C*O*
151714	S Serpentis	7.8	14.0	368.5	C
151731	S Coronae Bor.	6.7	12.7	361.2	B*OV*
151822	RS Librae	6.6	<12.0	217	C
152714	RU Librae	*8.5*	*<12.3*	316	C
152849	R Normae	7.0	11.5	480.7	C
153215	W Librae	9.8	15	205.5	C
153378	S Ursae Minoris	7.5	11.0	324	B*V*
153620	U Librae	9	<14	226.2	C
153654	T Normae	7.0	12.0	243.9	C
154428	R Coronae Bor.	5.5	12.5	Irr.	All
154536	X Coronae Bor.	8.3	14	250	JV
154615	R Serpentis	5.6	13	357.2	*BV*
154639	V Coronae Bor.	7.2	12.0	358	V
154715	R Librae	9.2	<13	242.4	C
154736	R Lupi	9.0	<12 ?	234.5	C
155018	RR Librae	8.4	14	276.7	C*V*
155229	Z Coronae Bor.	*8.0*	*<11*	. .	C
155823	RZ Scorpii	8.0	<13	161	C
160021	Z Scorpii	9	12 ?	366	C
160118	R Herculis	8.6	14.8	317.7	C
160210	U Serpentis	7.7	12.0	240	C
*160221*a	X Scorpii	10	<13	199	C
160524	RX Scorpii	*9*	*<12*	375	C
160625	RU Herculis	7.3	14.2	486	C
*161122*a	R Scorpii	9.5	16	224.1	C
*161122*b	S Scorpii	9.1	15	176.7	C
161138	W Coronae Bor.	7.8	14	236	A
161607	W Ophiuchi	8.9	<13.5	329.8	C
162112	V Ophiuchi	7.0	10.5	302.5	C
162119	U Herculis	6.4	12.0	403	*EOVY*
162319	Y Scorpii	10?	14	350	C
162807	SS Herculis	9.0	<12	100	C*V*
162815	T Ophiuchi	10	12.5	361	C
162816	S Ophiuchi	8.3	<13	233.8	C
163137	W Herculis	7.8	13.5	280.2	B*SVY*
163266	R Draconis	7.0	12.7	245.6	B*JOSVY*
164319	RR Ophiuchi	8.0	<12.0	298	C
164715	S Herculis	7.3	12.6	308.3	*BEJO*
164844	RS Scorpii	*7.0*	*11.4*	323	C*M*
165030	RR Scorpii	*7.0*	*12.1*	282	C*M*
165631	RV Herculis	9.0	15.8	204	OV
165636	RT Scorpii	*9.2*	*<12.9*	447	C
170215	R Ophiuchi	7.1	13.6	302.2	*JO*
170627	RT Herculis	9	14	303	C
170833	RW Scorpii	*9.4*	*14.1*	385	C
171401	Z Ophiuchi	7.5	12.5	349	C*V*
171723	RS Herculis	8.0	<12.5	221	C*V*
172586	S Octantis	*8.2*	*12.1*	259	C
172809	RU Ophiuchi	9	<12	202	C
173543	RU Scorpii	*9.4*	*13.4*	377	C
174135	SV Scorpii	8.8	<11.6	257	C
174162	W Pavonis	*9.1*	*<12.8*	282	C
174551	U Arae	*9.2*	*12.9*	224.5	C
175111	RT Ophiuchi	9.2	<13	426	C
175458	T Draconis	7.5	12.2	426	B*V*
175519	RY Herculis	8.5	14	223	C
175654	V Draconis	9.3	14.1	283	AB
180363	R Pavonis	8.0	12.0	229	C
180531	T Herculis	7.2	13.6	165	B*EOSV*
180565	W Draconis	9.0	<14	253	A
180666	X Draconis	*9.5*	*14*	271	A
181103	RY Ophiuchi	8.5	<10.4	154.5	C
181136	W Lyrae	7.6	12.5	197	EOY
182133	RV Sagittarii	*8.2*	*12.3*	319	C
182224	SV Herculis	9.5	<13	240	C
182306	T Serpentis	9.1	<13.5	341.8	C
183149	SV Draconis	*9*	*<12*	. .	A
183225	RZ Herculis	9	14	328	C
183308	X Ophiuchi	6.5	9.0	335	C
184134	RY Lyrae	10	*<14.5*	328	AV
184205	R Scuti	4.8	7.8	Irr.	*BEO*
184243	RW Lyrae	*9.0*	*<14.5*	496	AB

Design.	Name.	Max.	Min.	Period.	Observer.
*185512*a	ST Sagittarii	8.0	<12.5	395	C
185634	Z Lyrae	9	<12	290	A
190108	R Aquilae	5.8	<12	355	*B*C
190529a	V Lyrae	9.2	15.5	375	C
190818	RX Sagittarii	9.5	<13.3	332	C
*190819*a	RW Sagittarii	9.0	11.7	..	C
190925	S Lyrae	9.5	16	442	C
190967	U Draconis	9.0	13.5	318	H
191007	W Aquilae	7.5	13	487	C*V*
191017	T Sagittarii	7.2	12.0	381	C
191019	R Sagittarii	6.9	12.3	269	C*O*
191124	– Sagittarii	*8.5*	*<13.8*	..	C
191033	RY Sagittarii	6.5	<11.5	Irr.	C
191319	S Sagittarii	9.1	14.5	230.7	C
191321	Z Sagittarii	8.5	14.0	452	C
191331	SW Sagittarii	*9.1*	*<11.7*	289	C
191350	TZ Cygni	9.5	11.4	..	AB
191637	U Lyrae	8.3	<12	451	A
192928	TY Cgyni	8.7	<14	354	C
193311	RT Aquilae	8.0	<13	326	C
193449	R Cygni	6.6	13.9	425.9	B*OSV*
193509	RV Aquilae	9	<14	219	C
193972	T Pavonis	7.3	<12.5	244	C
194048	RT Cygni	6.7	12.0	190.5	B*OSV*
194348	TU Cygni	9	<13	218	B*V*
194604	X Aquilae	8.5	<13.5	348	C
194632	χ Cygni	4.0	13.5	406	B*JOV*
194929	RR Sagittarii	*7.5*	*<12.6*	335	C
195142	RU Sagittarii	*9*	*13.1*	242	C
195202	RR Aquilae	*8.4*	*<13.5*	395	C
195656	– Telescopii	*9.0*	*<11.5*	..	C
195849	Z Cygni	7.1	13	263	B*V*
195855	S Telescopii	*9.0*	*<12.5*	Irr.	C
200212	SY Aquilae	*9.5*	*<11.2*	357	C
200715a	S Aquilae	8.4	11.8	146.7	C
200747	R Telescopii	*8.4*	*11.6*	462	C
200812	RU Aquilae	8.5	14.5	276	C
200822	W Caprocorni	10.2	<14.7	208	C
200906	Z Aquilae	8.8	13	129	C
200938	RS Cygni	6.7	8.4	Irr.	B*J*
201008	R Delphini	7.6	13.0	284.4	*JOB*
201130	SX Cygni	9	14.5	409	Y
201139	RT Sagittarii	*7.7*	*10.7*	304	C*M*
201647	U Cygni	6.7	10.8	461.3	B*JOS*
202240	U Microscopii	*8.5*	*<12.5*	333	C
202622	RU Capricorni	9.4	<12.0	341	C
202817	Z Delphini	9.3	<12	303.4	C
202954	ST Cygni	9	14	335	B
203429	R Microscopii	*9.2*	*<11.7*	138.8	C
203611	Y Delphini	9	<13	487	C
203816	S Delphini	8.4	12.0	277.5	*VY*
203905	Y Aquarii	8.8	<13	382	C
204016	T Delphini	8.2	<13	331.2	*VY*
204104	W Aquarii	8.5	<13	383	C
204215	U Capricorni	10.2	14	202.5	C
204318	V Delphini	7.5	<17	532	C
204405	T Aquarii	6.7	13.0	203.3	*HJOV*
204846	RZ Cygni	9.1	13	273	BY
204954	S Indi	8.6	<12.5	404	C
205017	X Delphini	8	<13	281	C
205627	RR Capricorni	8.0	<12	240	C
205782	T Octantis	*9.0*	*<12.5*	218	C
205923	R Vulpeculae	7.5	12.1	136.8	*BJOV*
210124	V Capricorni	9	14.5	156.7	C
210129	TW Cygni	9.0	13.5	342	C
210221	X Capricorni	9.5	<16.2	218.1	C
210382	X Cephei	9.0	<17	543	BY
210504	RS Aquarii	9	<14	214	C
210516	Z Capricorni	9	<13	356	C
210812	R Equulei	8	<12	262	*AV*
210868	T Cephei	5.1	10.5	387	B*EOSV*
210903	RR Aquarii	8	13	180	C
211614	X Pegasi	8.5	13	200	C
211615	T Capricorni	8.8	13.5	269.2	C
212030	S Microscopii	7.9	11.5	213.2	C
212814	Y Capricorni	10	14	206	C
213678	S Cephei	7.9	13.1	485.8	B*EHJVS*
213843	SS Cygni	8.4	12.0	103.6	All
214024	RR Pegasi	9	13.5	265	C
214247	R Gruis	*8.4*	*12.5*	331	C
215605	V Pegasi	8.2	<14	303	C*V*
215828	S Piscis Aust.	8.7	<11	272	C
215934	RT Pegasi	9.5	<13	214.6	Y
220412	T Pegasi	8.5	<13	373.8	C*V*
220613	Y Pegasi	9.0	<12.5	206	C*V*
220714	RS Pegasi	8.8	<12.5	436	C*V*
221321	X Aquarii	7.7	12.5	315	C
221722	RT Aquarii	8.7	<11.5	241	C
221938	T Gruis	*8.6*	*11.0*	136	C
221948	S Gruis	*7.2*	*12.3*	402	C*M*
222129	RV Pegasi	*9*	*<11*	394	C*V*
222439	S Lacertae	8.0	12.5	237.5	VY
222867	R Indi	8.5	12.5	216	C
223462	T Tucanae	8	<14	250.6	C
223841	R Lacertae	8.3	14.5	299.8	B*VY*
225120	S Aquarii	8	14.2	279.7	C*H*
225914	RW Pegasi	*8.8*	*<12.6*	209	C*V*
230110	R Pegasi	7.5	13.2	377.5	*BHOYV*
230759	V Cassopeiae	7.1	12.4	230	EJV
231425	W Pegasi	7.5	13.5	342.4	C

Design.	Name.	Max.	Min.	Period.	Observer.	Design.	Name.	Max.	Min.	Period.	Observer.
231508	S Pegasi	7.8	12.9	317.5	C	*235209*	V Ceti	8.5	14.5	261	C
232746	V Phoenicis	*8.5*	<*12*	251	C	*235265*	R Tucanae	*10.2*	<*12.6*	275	C
233335	ST Andromedae	*8*	<*10.5*	310	HOS	235350	R Cassiopeiae	5.3	12.8	431.6	B*V*
233815	R Aquarii	6.2	11.0	387.16	C	235525	Z Pegasi	9	<11.5	319.7	C
233956	Z Cassiopeiae	8.5	15	505	AB	*235715*	W Ceti	6.5	12.0	366	C
235053	RR Cassiopeiae	9.6	<12.8	307	BV	235855	Y Cassiopeiae	9.0	13.9	411	B*V*
235150	R Phoenicis	7.4	13.0?	270	C*M*	235939	SV Andromedae	7.9	<13	298	BY

In 1881, a classification of variable stars was prepared by the writer (Proc. Amer. Acad. 16, 1), which still appears to be a natural one. The vast accumulation of additional facts since then permits a subdivision of the classes proposed at that time. Class Ia may be used to denote new stars, of the normal type like 052530, Nova Aurigae, and 032443, Nova Persei, No. 2. Class Ib, new stars like 003740, Nova Andromedae, and *133431*, Nova Centauri, which appear in nebulae and apparently have less marked bright lines than those of Class Ia. Class IIa, variables of long period of normal type, like *021403*, ο Ceti, and 194632, χ Cygni. Class IIb, stars which are ordinarily faint but suddenly become bright at irregular intervals of two or three months and then gradually fade. Only three stars are known of this class, 074922, U Geminorum, 213843, SS Cygni, and 060547, SS Aurigae. They should be watched carefully. Class IIc, stars which are ordinarily bright, but sometimes for a year or more, become faint without warning and vary very irregularly until they again attain their normal brightness. Only three stars are known to belong to this class, 154428, R Coronae Borealis, *191033*, RY Sagittarii, and 054319, SU Tauri. Class III, stars undergoing irregular variations like 054907, α Orionis and *184205*, R Scuti. Class IV, variables of short and nearly uniform period like 222557, δ Cephei and 065820, ζ Geminorum. Class V, variables of the Algol type like 030140, β Persei, and *145508*, δ Librae. Variables in which the maxima are of equal brightness, but are separated by minima which are alternately faint and bright like 184633, β Lyrae, and 235215, U Pegasi, should also be included in this Class. The subdivisions of Classes IV and V and the relation between them will be considered in a subsequent Circular.

EDWARD C. PICKERING.

JUNE 29, 1911.

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HARVARD COLLEGE OBSERVATORY.

CIRCULAR 167.

STARS HAVING PECULIAR SPECTRA. 31 NEW VARIABLE STARS.

A List of the variable stars and other objects having peculiar spectra discovered, by the late Mrs. Fleming, from an examination of the photographs of the Henry Draper Memorial, is probably completed in the present Circular. Similar objects recently found by other observers are also included.

Table I contains a list of the variable stars. The designation, the number, as assigned in the list of variables discovered at this Observatory, the constellation, the Durchmusterung number, the right ascension for 1900, and the declination for 1900, are given in the first six columns. The brightest and faintest observed magnitude, the difference, or range, the class of spectrum derived from the photographs, the number of photographs examined, and the name of the discoverer are given in the following six columns.

TABLE I.

NEW VARIABLE STARS.

Des.	H. V.	Constellation.	DM.		R.A. 1900.	Dec. 1900.	Bright.	Faint.	Range.	Spect.	No. Plates.	Discoverer.
					h. m.	° ′						
011556	3316	Phoenix	−56°	277	1 15.9	−56 26	8.5	16.0	7.5	Md	19	Fleming
023238	3317	Perseus	+38°	525	2 32.1	+38 44	11.0	<14.0	>3.0	N	25	Cannon
023530	3318	Triangulum	+30°	428	2 35.0	+30 47	10.0	11.5	1.5	Mc5	29	Leland
023534	3319	Perseus	+33°	490	2 35.4	+34 5	8.5	9.1	0.6	Mc5	41	Fleming
034025	3320	Fornax	. .		3 40.3	−25 32	9.8	<13.0	>3.2	. .	17	Mackie
044336	3321	Caelum	−36°	1884	4 43.8	−36 23	8.7	10.3	1.6	N	33	Fleming
051532	3322	Auriga	+32°	957	5 15.3	+32 24	9.2	10.6	1.4	Md	32	Fleming
054046	3323	Pictor	−46°	1969	5 40.4	−46 30	11.0	<15.0	>4.0	N	19	Wells
065041	3324	Auriga	+41°	1556	6 50.3	+41 14	9.6	12.6	3.0	N	17	Fleming
070207	3325	Monoceros	− 7°	1742	7 2.1	− 7 24	12.8	14.0	1.2	. .	13	Wells

Des.	H. V.	Constellation.	DM.	R.A. 1900.	Dec. 1900.	Bright.	Faint.	Range.	Spect.	No. Plates.	Discoverer.
				h. m.	° ′						
094641	3326	Vela	−41° 5381	9 46.0	−41 34	9.2	10.5	1.3	Mc5	23	Fleming
111819	3327	Crater	−19° 3254	11 18.9	−19 22	9.2	10.2	1.0	Mc5	22	Fleming
131044	3328	Centaurus	−44° 8539	13 10.7	−44 10	9.0	9.6	0.6	Pec.	14	Fleming
181021	3329	Sagittarius	. .	18 10.7	−21 36	11.8	<15.0	>3.2	. .	260	Breslin
182216	3330	Sagittarius	. .	18 22.3	−16 50	10.9	<15.0	>4.1	Md	16	Fleming
182604	3331	Ophiuchus	+ 4° 3779	18 26.4	+ 4 19	14.0	15.0	1.0	N	23	Wells
183242	3332	Coron. Austr.	−42° 13488	18 32.9	−42 41	12.2	15.5	3.3	. .	24	Mackie
185200	3333	Aquila	+ 0° 4064	18 52.5	+ 0 19	9.6	11.0	1.4	. .	48	Wells
185414	3334	Aquila	+14° 3729	18 54.0	+14 14	9.6	11.6	2.0	. .	33	Wells
191117	3335	Sagittarius	. .	19 11.9	−17 39	10.0	14.0	4.0	. .	9	Mackie
191632	3336	Sagittarius	−32° 15116	19 16.3	−32 19	10.3	14.0	3.7	. .	10	Mackie
192118	3337	Sagittarius	. .	19 21.2	−18 43	9.4	15.0	5.6	Md	15	Fleming
200020b	3338	Sagitta	+20° 4417	20 0.7	+20 22	10.0	12.0	2.0	N	28	Wells
201737	3339	Cygnus	+37° 3903	20 17.9	+37 13	11.5	12.5	1.0	. .	15	Wells
203246	3340	Indus	−47° 13487	20 32.2	−46 57	10.3	11.1	0.8	Md?	27	Fleming
205833	3341	Microscop.	. .	20 58.4	−33 40	9.3	<15.0	>5.7	Md	18	Fleming
210415	3342	Pegasus	. .	21 4.3	+15 38	10.1	<14.0	>3.9	Md	25	Cannon
212545	3343	Grus	−45° 14361	21 25.3	−45 29	9.8	14.0	4.2	. .	38	Mackie
224930	3344	Piscis Austr.	−30° 19355	22 49.8	−30 9	8.4	9.7	1.3	Mc5	29	Fleming
225745	3345	Andromeda	+45° 4121	22 57.2	+45 21	11.5	12.2	0.7	. .	14	Wells
234860	3346	Cassiopeia	+60° 2634	23 48.0	+60 27	11.0	11.7	0.7	Mc	24	Wells

REMARKS.

070207. Spectrum Type IV, according to Espin. No trace of spectrum seen on several good photographs.

181021. This is a variable star of the Algol type. It is faint on 6 of the 260 photographs examined by Miss Breslin.

185200. Spectrum Type IV, according to Espin. Too faint on the photographs to classify.

185414. Spectrum Type IV, according to Vogel. Spectrum is barely seen on the best photographs, and is too faint to classify.

201737. See 185200.

210415. This is a variable star of long period. The formula for times of maximum, J.D. 2410088 + 122^d E, was found by Miss Cannon from an examination of 25 photographs.

225745. See 185200.

234860. Spectrum Type IV, according to Espin.

In addition to these new variable stars, the three stars, −19° 4644, +43° 3425, and +41° 3632, which have previously been announced by Espin and Backhouse to be variable, have been found independently by Miss L. D. Wells, and their variability has been confirmed on from 11 to 24 photographs.

Table II contains a list of the stars having peculiar spectra. The Durchmusterung number, the right ascension for 1900, the declination for 1900, the Durchmusterung magnitude, the class of spectrum, a brief description of the spectrum, and the name of the discoverer are given in the successive columns.

TABLE II.

PECULIAR SPECTRA.

DM.	R.A. 1900.		Dec. 1900.		Magn.	Spectrum.	Description.	Discoverer.
	h.	m.	°	′				
+41° 1556	6	50.3	+41	14	9.3	N	Normal fourth type	Fleming
−11° 1760	6	59.0	−11	24	9.0	O	Bright lines	Fleming
−58° 1865	10	1.2	−58	11	9.0	R	Hβ bright	Fleming
−61° 3787	13	26.4	−61	50	9.7	O	Bright lines	Fleming
−32° 12518	17	9.0	−32	32	8.0	B 8 p	Hβ bright	Cannon
. . .	17	53.3	−38	49	. .	P	Bright lines. Gaseous nebula	Fleming
+57° 2374	21	39.3	+57	17	7.2	Bp	Hβ bright	Cannon

REMARKS.

h. m.

6 59.0. Galactic longitude, 192° 16′; galactic latitude, −1° 13′.

10 1.2. Hβ is a well marked bright line. Spectrum otherwise is nearly continuous.

h. m.

13 26.4. Galactic longitude, 275° 27′; galactic latitude, −0° 20′.

17 53.3. Galactic longitude, 321°; galactic latitude, −9°.

EDWARD C. PICKERING.

SEPTEMBER 20, 1911.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 168.

THE VARIABLE STAR, 232848, Z ANDROMEDAE.

THE variability of the star 232848, Z Andromedae, was discovered by Mrs. Fleming in 1901, and announced in H.C. 54. This star is + 48° 4093, magn. 9.5. The only other observation that appears to have been published of it is by Hartwig, that its magnitude was 9.0 on August 2, 1901. Astron. Nach. 156, 374. Measures of the photographic brightness of this star have been made on 273 plates, and those preceding 1906 will be published shortly in H.A. 47, Part 2. Table I has been prepared from the results there given, and from

TABLE I.

Z ANDROMEDAE.

Date.	J. D.	Magn.	No.	Date.	J. D.	Magn.	No.	Date.	J. D.	Magn.	No.
1887 11 30	0606	11.02	3	1901 6 28	5564	10.57	1	1904 12 20	6835	11.01	10
1890 10 15	1656	11.44	3	" 8 24	5621	9.32	6	1905 6 27	7024	10.52	2
1891 10 28	2034	11.02	3	" 10 23	5681	9.11	9	" 10 18	7137	10.96	6
1892 9 15	2357	11.33	5	" 12 12	5731	9.13	10	" 11 30	7180	10.94	8
1893 8 3	2679	11.10	4	1902 1 30	5780	9.21	6	1906 2 2	7244	10.80	2
" 11 4	2772	10.87	2	" 5 28	5898	9.57	1	" 9 2	7456	10.94	5
1894 9 11	3083	11.36	1	" 8 16	5978	9.64	9	" 12 30	7575	11.00	2
1895 8 28	3434	10.07	4	" 10 20	6043	10.10	10	1907 7 15	7772	10.76	3
1896 10 5	3838	11.00	5	" 12 21	6105	10.28	11	" 11 17	7897	11.22	5
1897 1 17	3942	10.20	8	1903 2 6	6152	10.20	5	1908 7 22	8145	11.08	2
" 8 26	4163	10.84	6	" 7 30	6326	9.91	4	" 11 18	8264	10.99	5
1898 10 20	4583	9.72	9	" 10 16	6404	9.83	11	1909 9 10	8560	11.04	2
1899 1 3	4658	9.95	2	" 12 1	6450	10.12	16	" 12 30	8671	11.06	5
" 9 4	4902	10.08	7	1904 1 11	6491	10.27	7	1910 7 13	8866	10.59	2
" 11 16	4975	9.80	7	" 7 16	6678	10.82	6	" 12 7	9013	11.10	3
1900 8 14	5246	10.27	5	" 9 21	6745	10.84	9	1911 7 12	9230	11.22	2
1901 1 9	5394	10.77	4	" 11 10	6795	10.99	10				

measures of later plates. When several photographs were taken within a few days of each other, they were combined in a single group. The mean calendar date, the corresponding Julian Day, the mean magnitude and the number of photographs in the group are given in the successive columns. The scale of magnitudes depends on the adopted magnitude of the comparison stars in the last column of Table I in H.A. 47, p. 87.

The nature of the light curve is best shown in Figure 1 in which abscissas give the times on a scale of 1000 days = 1 cm., and ordinates give the magnitudes, on a scale of 1 magn. = 1 cm. As each point, in general, depends on accordant measures of several plates, it is difficult to avoid the conclusion that the observed variations are real. Thus, the magnitudes in the group whose mean Julian Day is 3838, are, 11.02, 11.02, 11.02, 11.36, and 10.57; those of Julian Day 3942, 10.18, 10.24, 10.18, 10.08, 10.18, 10.47, 10.08, and 10.18; those of Julian Day 4163, 11.02, 10.92, 10.57, 10.97, 11.02 and 10.52. For the last six years the light appears to have been nearly constant, magnitude 11.0. The principal outburst was in 1901, when the star attained the magnitude 9.2. It thus appears that the light curve is very peculiar, and unlike that of any other star so far observed.

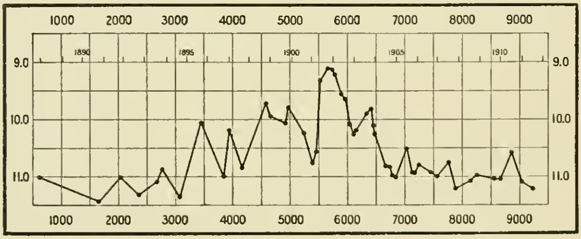

FIG. 1.

An examination of the photographic spectrum of this star has been made by Miss Cannon, who finds that the spectrum is unlike that of variable stars of long period, and resembles that of several new stars. This had already been suspected by Mrs. Fleming, who recorded on the cover of Plate I 25940, taken October 17, 1900, "Bright lines. Nova or Var. ?" The spectrum, as seen on the best photographs, resembles that of Nova Persei, No. 2, on April 12, 1901. H.A. 56, Plate I. It also resembles that of Nova Geminorum on March 29, 1903, of Nova Sagittarii, No. 1, on April 21, 1898, and of

RS Ophiuchi on July 15, 1898, at or near the time of the remarkable outburst of light in that object, to which attention is called in H.C. 99. The spectrum of Z Andromedae, although fainter than those of the Novae referred to above, shows clearly the bright lines, Hβ, Hγ, Hδ, and Hε, and also one at about the wave length 4688, which probably coincides with the bright band in stars of the fifth type.

EDWARD C. PICKERING.

NOVEMBER 10, 1911.

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UNIVERSITY OF

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 169.

PHOTOMETRIC OBSERVATIONS OF ASTEROIDS.

One of the most important problems in Astronomical Photometry, is the determination of the light of the asteroids. The problem is a very complicated one, since the light varies not only with the distance from the Sun and Earth, but also with the phase angle, according to a curious law. Several observers have shown that this variation is proportional to the phase angle, a law for which no physical explanation has been offered. In addition, Eros and some other asteroids have been found to vary in a period of several hours. These changes are very puzzling, since they sometimes cease, or the range alters, without obvious cause.

It is probable that the photometry of the asteroids, in the future, will be studied mainly by photography as soon as a satisfactory scale of photographic magnitudes can be established for all the stars. At present, several series of photometric measures have been made visually. The results of these measures are given in Table I. The first three columns give the number of each asteroid, its name, and the value of *g*, or magnitude given each year in the Berliner Jahrbuch, assuming that the asteroid is at a distance from the Sun and from the Earth equal to unity, the mean distance of the Earth from the Sun. The next seven columns give the resulting values for the same quantity found by Müller with a Zöllner Photometer, Publikationen des Astrophysikalischen Observatoriums zu Potsdam, 8, 370; by H. M. Parkhurst, who made three series in 1887, 1888, and 1889, with a photometer in which the limit of visibility was measured, the aperture of the telescope being reduced by a known amount, H.A. 29, 86; by Searle and Wendell who determined the limit of visibility by means of a wedge of shade glass, placed in the focus of the 15-inch East Equatorial, H.A. 33, No. 1; by E. C. Pickering who measured the four brightest asteroids with the

4-inch meridian photometer, H.A. 46, 197. The mean of these values and the residuals from the mean are given in the next eight columns. The next two columns give the value of m_0, or magnitude at mean opposition as given in the Berliner Jahrbuch, and the residual found by subtracting the mean photometric magnitude from the value of g given in the third column. This residual will be the same whether we use the value of g, or m_0, since the relation of these quantities is determined by computation, and not by observation. The last column gives the residual found after applying the correction 0.2 (m_0 — 9.0) to the residual in the preceding column. This correction is derived from the discussion given in Table II.

TABLE I.

PHOTOMETRIC OBSERVATIONS.

No.	Name.	g	M.	1887.	1888.	1889.	S.	W.	P.	Mean.	M.	1887.	1888.	1889.	S.	W.	P.	m_0	Res.	Corr.
1	Ceres	4.0	3.46	3.76	3.74	..	..	3.84	3.69	3.70	*.24*	.06	.04	..	..	.14	*.01*	7.4	.30	*.02*
2	Pallas	4.5	4.10	4.50	..	..	..	..	4.54	4.38	*.28*	.12	..	..	..	..	.16	8.0	.12	*.08*
3	Juno	5.5	..	5.77	..	5.77	5.71	4.61	5.72	5.74	..	.03	..	.03	*.03*	R	*.02*	8.7	*.24*	*.30*
4	Vesta	4.0	3.47	3.46	3.49	3.49	..	4.25	3.57	3.50	*.03*	*.04*	*.01*	*.01*	..	R	.07	6.5	.50	.00
5	Astraea	6.9	..	..	7.06	..	..	..	..	7.06	..	..	A	..	..	..	..	9.9	*.16*	.02
6	Hebe	5.8	5.83	..	..	6.33	..	..	..	6.08	*.25*	..	..	.25	..	..	..	8.5	*.28*	*.38*
7	Iris	5.8	5.86	6.39	6.30	..	..	5.89	..	6.11	*.25*	.28	.19	..	..	*.22*	..	8.4	*.31*	*.43*
8	Flora	6.8	6.82	..	6.67	6.71	6.43	6.67	..	6.66	.16	..	.01	.05	*.23*	.01	..	8.9	.14	.12
9	Metis	6.3	6.10	..	..	..	..	..	..	6.10	A	..	..	..	..	..	..	8.9	.20	.18
11	Parthenope	6.5	..	..	6.92	6.92	6.58	6.26	..	6.67	..	..	.25	.25	*.09*	*.41*	..	9.3	*.17*	*.11*
12	Victoria	7.2	..	..	..	7.66	..	..	..	7.66	..	..	..	A	..	..	..	9.7	*.44*	*.30*
14	Irene	6.6	6.57	.	..	..	..	..	..	6.57	A	..	..	..	..	..	..	9.7	.03	.17
15	Eunomia	5.4	5.67	..	..	..	..	..	..	5.67	A	..	..	..	..	..	..	8.6	*.27*	*.19*
16	Psyche	5.9	..	5.26	5.79	5.83	..	..	..	5.63	..	*.37*	.16	.20	..	..	..	9.6	.27	.39
18	Melpomene	6.9	..	6.59	..	6.59	..	..	..	6.59	..	.00	..	.00	..	..	..	9.3	.31	.37
19	Fortuna	7.1	..	..	..	7.23	..	..	..	7.23	..	..	..	A	..	..	..	9.8	*.13*	.03
20	Massalia	6.5	6.52	..	6.44	6.40	..	..	..	6.45	.07	..	*.01*	*.05*	..	..	..	9.2	.04	.08
21	Lutetia	7.4	7.37	..	..	..	..	..	..	7.37	A	..	..	..	..	..	..	10.1	.03	.25
23	Thalia	7.3	..	..	6.65	..	..	..	..	6.65	..	..	A	..	..	..	..	10.5	.65	.95
25	Phocaea	7.9	..	8.14	..	..	..	..	..	8.14	..	A	..	..	..	..	..	10.5	*.24*	.06
27	Euterpe	7.2	..	8.71	..	6.88	..	..	..	R	..	R	..	R	..	..	..	9.7	..	..
28	Bellona	6.6	..	..	7.40	..	..	..	..	7.40	..	..	A	..	..	..	..	10.1	*.80*	*.58*
29	Amphitrite	6.1	5.90	..	5.80	..	..	..	..	5.85	.05	..	*.05*	..	..	..	..	9.0	.25	.25
30	Urania	7.4	..	7.88	..	7.88	..	..	..	7.88	..	.00	..	.00	..	..	..	9.9	*.48*	*.30*
37	Fides	7.2	7.22	6.70	..	..	..	..	..	6.96	.26	*.26*	..	..	..	..	..	10.4	.24	.52
39	Laetitia	6.0	6.22	..	..	..	..	..	..	6.22	A	..	..	..	..	..	..	9.5	*.22*	*.12*

No.	Name.	*g*	M.	1887.	1888.	1889.	S.	W.	P.	Mean.	M.	1887.	1888.	1889.	S.	W.	P.	m_0	Res.	Corr.
40	Harmonia	6.9	7.02	7.89	7.66	..	..	..	..	7.52	*.50*	.37	.14	..	..	..	..	9.2	*.62*	*.58*
41	Daphne	7.0	7.59	..	..	..	..	..	..	7.59	A	..	..	..	..	..	..	10.5	*.59*	*.29*
42	Isis	7.7	..	8.38	..	..	..	..	..	8.38	..	A	..	..	..	..	..	10.4	*.68*	*.40*
43	Ariadne	7.9	..	8.27	..	..	..	..	..	8.27	..	A	..	..	..	..	..	10.0	*.37*	*.17*
44	Mysa	7.1	..	7.81	7.16	..	..	..	..	7.48	..	.33	*.32*	..	..	..	..	9.8	*.38*	*.22*
51	Nemausa	7.3	..	7.39	..	..	..	..	..	7.39	..	A	..	..	..	..	..	9.8	*.09*	.07
75	Eurydike	8.4	..	..	9.36	..	..	..	..	9.36	..	..	A	..	..	..	..	11.6	*.96*	*.44*
82	Alkmene	7.8	..	..	..	..	8.21	8.32	..	8.26	..	..	..	..	*.05*	.06	..	11.2	*.46*	*.02*
105	Artemis	8.5	..	..	..	8.09	..	..	..	8.09	..	..	..	A	..	..	..	11.1	.41	.83
110	Lydia	7.1	..	..	8.91	..	..	..	..	8.91	..	..	A	..	..	..	..	10.5	*1.81*	*1.51*
114	Kassandra	7.8	..	7.15	..	..	..	..	..	7.15	..	A	..	..	..	..	..	11.1	.65	1.09
122	Gerda	7.2	..	..	6.13	..	..	..	..	6.13	..	..	A	..	..	..	..	11.5	1.07	1.57
127	Johanna	7.1	..	..	9.27	..	..	..	..	9.27	..	..	A	..	..	..	..	10.5	*2.17*	*1.87*
187	Lamberta	8.0	..	9.51	..	..	..	..	..	9.51	..	A	..	..	..	..	..	11.4	*1.51*	*1.03*
192	Nausikaa	6.7	6.99	..	7.37	..	..	..	..	7.18	*.19*	..	.19	..	..	..	..	9.3	*.48*	*.42*
200	Dynamena	7.9	..	..	8.74	..	..	..	..	8.74	..	..	A	..	..	..	..	11.3	*.84*	*.38*
261	Prymno	9.0	..	..	10.28	..	..	..	..	10.28	..	..	A	..	..	..	..	11.5	*1.28*	*.78*

The numbers of asteroids measured in the seven series of observations are, 18, 18, 20, 13, 4, 7, and 4. Many of these appear in only one series, so that the numbers of residuals are, 11, 11, 11, 9, 4, 5, and 4, and their average values are, .21, .17, .12, .09, .10, .17, and .06. The measures of Juno (3) by Pickering in successive oppositions, 5.92 and 5.51, differ much more than the accidental errors would indicate, but their mean has been retained, since it agrees closely with the results of the other observers. The measures of Juno (3) and Vesta (4), by Wendell, have been rejected for discordance. The two sets of measures of Euterpe (27) by Parkhurst differ widely and are also rejected.

A grouping was next made of the residuals in the last column but one of Table I for each half magnitude of m_0. The results are given in Table II. The mean value of m_0, the number of asteroids, and the mean of the residuals are given in the first three columns. A second grouping was made of the separate measures, that is, giving to each asteroid a weight equal to the number of the seven series in which it occurs. The number and mean residual are given in the fourth and fifth columns. The relation of these residuals to the values of m_0 contained in the first column is closely represented by the term, $0.2\,(m_0 - 9.0)$. This is preferred to a value derived by least squares, for convenience of calculation, since m_0 is only expressed in tenths of a magnitude, and the hundredths would be fictitious. The computed value of this correction is given in the sixth column, and the difference found by subtracting the sixth from the fifth column, is given in the seventh column. The eighth column is found by subtracting the fifth column from the first and gives the corresponding photometric magnitude. The relation between the first and eighth columns is shown in Figure 1 by the circular dots, and the assumed correction by the heavy line.

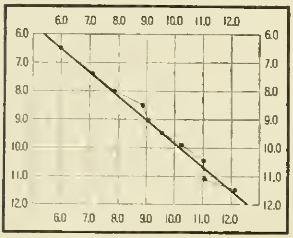


FIG. 1.

The photometric magnitudes corresponding to the values of m_0, given in the Berliner Jahrbuch, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, and 13.0 are accordingly 6.6, 7.8, 9.0, 10.2, 11.4, 12.6 and 13.8.

TABLE II.

GROUPING OF RESIDUALS.

m_0	No.	Res.	No.	Res.	Corr.	O—C.	Ptm.	m_0	No.	Res.	No.	Res.	Corr.	O—C.	Ptm.
6.5	1	.50	5	.50	.50	.00	6.00	9.49	7	*.03*	14	*.06*	*.10*	.04	9.55
7.4	1	.30	5	.30	.32	*.02*	7.10	9.92	8	*.30*	10	*.32*	*.18*	*.14*	10.24
8.0	1	.12	3	.12	.20	*.08*	7.88	10.47	7	*.66*	8	*.54*	*.29*	*.25*	11.01
8.55	4	*.28*	11	*.28*	.09	*.37*	8.83	11.13	3	.20	4	.04	*.43*	.46	11.09
9.04	5	.00	14	*.02*	*.01*	*.01*	9.06	11.46	5	*.70*	5	*.70*	*.49*	*.21*	12.16

In photometric observations of the asteroids, the ephemerides of the British Nautical Almanac are extremely convenient. They give the positions of the first four asteroids throughout the year. It is unfortunate that similar tables should not be published for Eros and a few other objects of especial interest, for instance, those whose light has been found to vary. The value of these ephemerides would be greatly increased if the value of the phase angle was also given, as this quantity is indispensable in reducing photometric observations.

EDWARD C. PICKERING.

DECEMBER 14, 1911.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 170.

ADOPTED PHOTOGRAPHIC MAGNITUDES OF 96 POLAR STARS.

A METHOD of finding photographic magnitudes, on a uniform scale, for stars in different parts of the sky, by means of plates having duplicate exposures on the North Pole and on the given region, was described in Circular 108. Provisional photographic magnitudes for a sequence of 10 stars near the North Pole are given in Circular 125, and a fuller description of the method is contained in Circular 150. The number of Standard Polar Stars has now been increased to 96 and their photographic magnitudes have been determined on an absolute scale. As the results may be of immediate use to some astronomers, they are given here, in advance of the full discussion of the observations, which is in preparation for the press. The greater portion of the work has been done by Miss Leavitt, who has prepared the following statement of the investigations contained in the two portions of this Circular.

The Standard Polar Stars are divided into three groups, the North Polar Sequence, the North Polar Sequence of Red Stars, and the Supplementary Stars near the North Pole. The North Polar Sequence is composed of white stars, so far as the colors are known. The stars brighter than the magnitude 11.3 have spectra of Class A, with one exception, while fainter stars to the fifteenth magnitude have been found to be relatively white by means of isochromatic plates taken with a yellow screen. Measures of the Polar Standards were made on more than 300 photographs, taken with the 13 following instruments: 0.5-inch Ross-Zeiss Lens, 1-inch Cooke Anastigmat, 4-inch Cooke Anastigmat, 8-inch Bache Doublet, 8-inch Draper Doublet, 11-inch Draper Telescope, 12-inch Metcalf Doublet, 13-inch Boyden Telescope, 16-inch Metcalf Doublet, 24-inch Reflector, 24-inch Yerkes Reflector, 36-inch Crossley Reflector, 60-inch Mount Wilson Reflector. The photographs taken with the three large reflectors last mentioned were kindly loaned by the Directors of the Yerkes, Lick, and Mount Wilson Observatories and have made it possible to determine the brightness of stars as faint as the twenty-first magnitude. Approximate values of the limiting magnitudes for given exposures, as observed on plates of average quality, are as follows: 0.5-inch Ross-Zeiss, 60^m, 9.7; 1-inch Cooke, 60^m, 11.5; 4-inch Cooke, 10^m, 12.4, 60^m, 13.3; 8-inch Draper 10^m, 13.8, 60^m, 15.0; 11-inch Draper, 10^m, 14.4, 60^m, 15.6; 12-inch Metcalf, 60^m, 16.8 (1 plate); 16-inch Metcalf, 10^m, 15.0, 60^m, 16.5; 24-inch Reflector, 60^m, 16.5; Yerkes Reflector, 45^m, 17.7 (1 plate); Crossley Reflector, 60^m, 18.9 (1 plate); Mount Wilson Reflector, 40^m, 19.1, 240^m, 21.0 (1 plate).

In order to determine magnitudes on an absolute scale, the following methods were used: (1) Exposures with different foci, as described in H.A. 59, Nos. 4 and 5. (2) Two plates of Iceland spar interposed before the sensitive film; the relative brightness of the two pairs of images of each star depends on the angle at which the Iceland spar plates are turned. (3) Two exposures of equal length, on the same plate, taken with and without a wire screen placed over the objective. (4) Three exposures of equal length on the same plate, taken with full aperture, and with the halves of the objective successively covered. (5) Secondary images formed by an auxiliary prism of very small angle, which is attached to the objective of the 8-inch Draper Doublet, and deflects about a hundredth part of the light. (6) Two exposures of equal length, on the same plate, taken with and without a circular diaphragm placed over the objective. An absolute scale of magnitudes was derived separately from each of about 80 plates taken by the above methods, the starting point in every case being the mean photometric magnitude of such stars in the Polar Sequence, given in Table I, as were measured on that plate. The plates were next arranged in 20 groups, each containing from 3 to 7 plates taken by the same method. The mean magnitude of every star was then taken for each group, and finally the mean of the resulting magnitudes was taken. The magnitudes depending on the different methods were more accordant than was expected. The average deviation of a single group from the mean was ±0.091 for 70 stars. The 26 stars omitted were measured on a small number of plates, or on one only. They were all fainter than the eighteenth magnitude. For 48 stars, brighter than the magnitude 14.9, the average deviation is ±0.070 magn. The accidental errors of the adopted magnitudes were rendered extremely small, by means of measures made on more than 200 additional chart plates.

In Tables I, II, and III, the first four columns give the designation, and the numbers in H.A. 50, H.A. 18, 7, and H.A. 48, 1. The number in the third column refers to Table XI in H.A. 18, 7, unless it is given in Italics, when it refers to Table III. The fifth column gives the number in the Greenwich Astrographic ·Catalogue, the letter which follows referring to an individual plate, as explained in the Greenwich Second Nine-Year Catalogue of Stars for 1900, Part II, page xxxvi. The number in the Bonn Durchmusterung, right ascension for 1900, declination for 1900, standard coordinates in x and y, and north polar distance, are given in the sixth to the eleventh columns, inclusive. The distances in the ninth, tenth and eleventh columns are expressed in seconds of arc, negative values being indicated by Italics. The position of No. 38s is approximate only, as the image is extremely faint, and difficult to measure. The twelfth and thirteenth columns contain the photometric magnitude and the adopted photographic magnitude. The difference found by subtracting the photometric from the photographic magnitude is given in the fourteenth column, negative differences being expressed in Italics. The class of spectrum, when known, is contained in the last column.

TABLE I.

THE NORTH POLAR SEQUENCE.

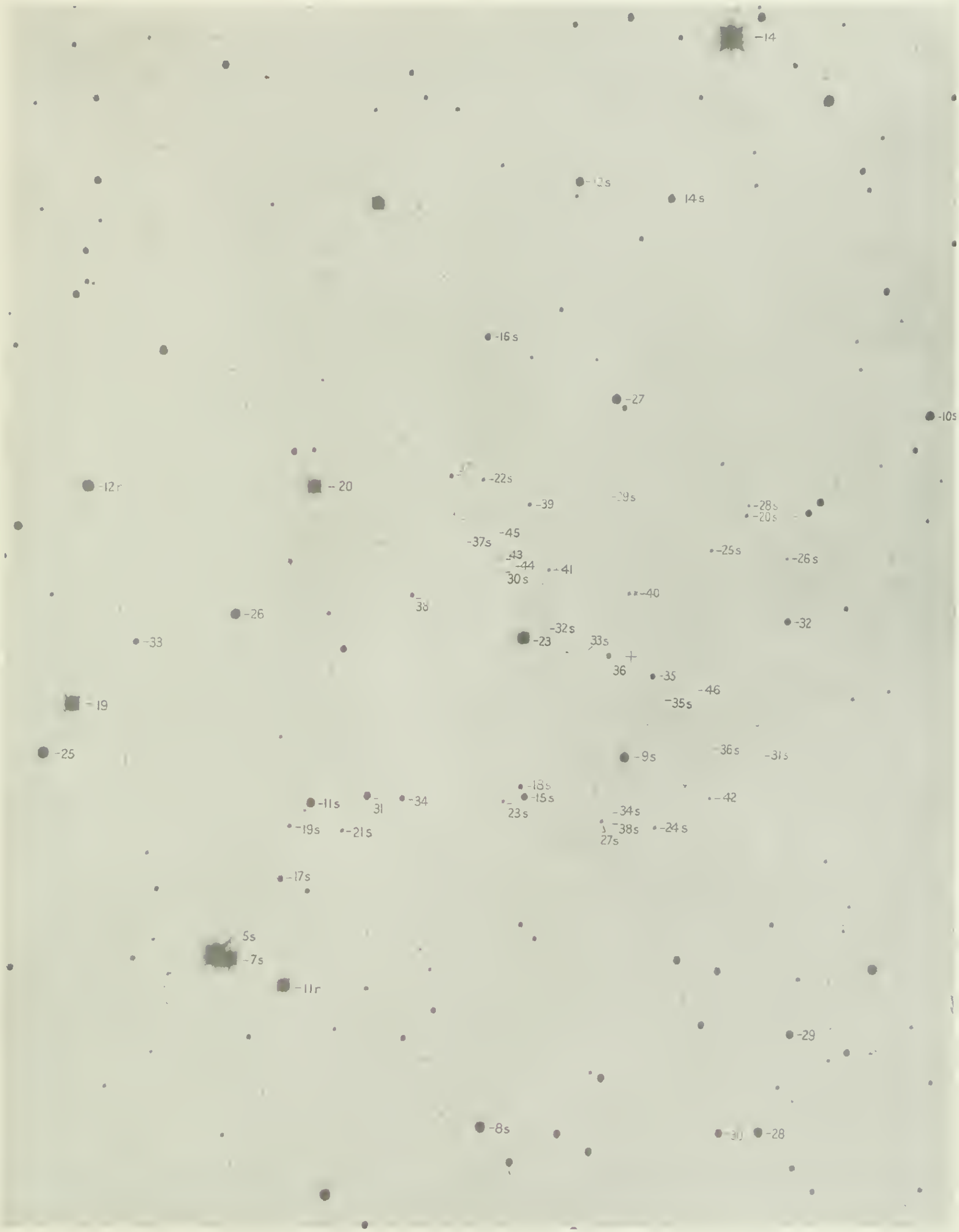
Des.	H.R.	18	48	Greenwich.	DM.	R.A. 1900.	Dec. 1900.	x	y	N.P.D.	Ptm.	Ptg.	Diff.	Sp.
						h. m.	° ′	″	″	″				
1	6789	..	..	1241	+86° 269	18 4.6	+86 36.8	234	*12192*	12192	4.44	4.47	0.03	A 1
2	8546	..	..	2389	+85° 383	22 21.3	+85 36.3	14370	*6610*	15823	5.38	5.24	*0.14*	A 0
3	8938	*44*	..	1719	+86° 344	23 27.8	+86 45.3	11570	*1625*	11679	5.62	5.74	0.12	A 2
4	6811	*26*	..	9k	+86° 272	18 7.8	+86 59.6	378	*10820*	10822	5.86	5.91	0.05	A 3
5	286	..	..	126a	+88° 4	0 55.6	+88 29.3	5285	1308	5445	6.43	6.39	*0.04*	A
6	..	181	..	215d	+89° 13	7 58.0	+88 56.0	*1891*	3343	3841	7.01	6.98	*0.03*	A
7	..	*82*	..	159f	+88° 64	11 4.2	+88 11.0	*6344*	1582	6539	7.44	7.18	*0.26*	A
8	..	..	..	153a	+88° 9	2 14.2	+88 42.1	3892	2586	4673	7.97	8.10	0.13	F
9	..	..	..	154a	+88° 13	2 42.2	+88 34.1	3912	3353	5152	8.61	8.70	0.09	A
10	..	618	420	174P	+89° 3	3 18.9	+89 41.2	728	860	1128	8.94	8.89	*0.05*	A
11	..	185	8	56P	+89° 18	11 35.0	+89 29.1	*1845*	202	1856	9.30	9.42	0.12	A
12	..	206	17	71P	+89° 25	13 51.5	+89 28.9	*1650*	*873*	1867	9.54	9.73	0.19	A
13	..	321	101	98P	+89° 29	15 13.6	+89 38.4	*860*	*973*	1299	10.25	10.17	*0.08*	A
14	..	587	386	165P	+89° 1	0 34.0	+89 51.2	523	78	529	10.44	10.52	0.08	A ?
15	..	417	197	117P	...	7 43.2	+89 45.3	*384*	796	883	10.78	10.94	0.16	A
16	..	608	408	177P	...	20 55.2	+89 43.2	696	*725*	1006	11.07	11.26	0.19	A ?
17	..	494	282	141P	...	18 1.2	+89 40.2	6	*1186*	1187	11.18	11.49	0.31	..
18	..	524	320	155P	...	18 43.6	+89 43.6	186	*966*	984	11.93	11.92	*0.01*	..
19	..	480	268	137P	...	17 33.6	+89 52.2	*54*	*467*	470	12.22	12.28	0.06	..
20	..	516	302	153P	...	19 46.8	+89 55.0	134	*267*	299	12.65	12.59	*0.06*	..
21	..	458	248	140P	...	17 21.6	+89 44.6	*154*	*910*	923	..	12.82	..	..

Des.	H.R.	18	48	Greenwich.	DM.	R.A. 1900.	Dec. 1900.	x	y	N.P.D.	Ptm.	Ptg.	Diff.	Sp.
						h. m.	° ′	″	″	″				
22	. .	506	292	139P	. . .	18 15.6	+89 46.2	57	*825*	827	. .	13.05	. .	. .
23	. .	497	284	136P	. . .	18 30.4	+89 58.6	12	*86*	87	13.34	13.20	*0.14*	. .
24	. .	489	279	138P	. . .	17 57.2	+89 49.6	*8*	*626*	626	. .	13.50	. .	. .
25	. .	473	263	. .	. . .	17 15.6	+89 51.7	*96*	*489*	499	. .	13.73	. .	. .
26	. .	501	288	. .	. . .	18 17.2	+89 54.5	25	*331*	332	. .	14.19	. .	. .
27	. .	531	324	. .	. . .	23 46.8	+89 56.4	216	*12*	215	. .	14.55	. .	. .
28	. .	414	190	. .	. . .	10 51.4	+89 53.0	*403*	124	421	. .	14.97	. .	. .
29	. .	429	212	. .	. . .	10 19.8	+89 54.1	*319*	149	352	. .	15.52	. .	. .
30	. .	189	. .	. .	. . .	11 10.0	+89 53.1	*404*	90	414	. .	15.90	. .	. .
31	. .	. .	257	. .	. . .	15 59.2	+89 55.9	*125*	*215*	249	. .	16.08	. .	. .
32	. .	. .	289	. .	. . .	5 11.2	+89 57.7	30	138	141	. .	16.48	. .	. .
33	. .	. .	. .	. .	. . .	18 0.0	+89 53.1	0	*413*	413	. .	16.82	. .	. .
34	. .	. .	. .	. .	. . .	15 42.7	+89 56.2	*127*	*186*	225	. .	17.11	. .	. .
35	. .	. .	. .	. .	. . .	8 50.0	+89 59.5	*22*	24	32	. .	17.36	. .	. .
36	. .	. .	. .	. .	. . .	18 0.0	+89 59.8	0	*11*	11	. .	17.61	. .	. .
37	. .	. .	. .	. .	. . .	20 56.0	+89 56.6	143	*148*	206	. .	17.80	. .	. .
38	. .	. .	. .	. .	. . .	18 58.0	+89 56.9	46	*178*	184	. .	18.17	. .	. .
39	. .	. .	. .	. .	. . .	21 42.2	+89 57.5	123	*82*	148	. .	18.53	. .	. .
40	. .	. .	. .	. .	. . .	0 38.6	+89 59.1	53	9	54	. .	18.89	. .	. .
41	. .	. .	. .	. .	. . .	21 8.8	+89 58.5	68	*63*	93	. .	19.13	. .	. .
42	. .	. .	. .	. .	. . .	9 52.3	+89 57.6	*122*	76	144	. .	19.54	. .	. .
43	. .	. .	. .	. .	. . .	20 24.4	+89 57.8	78	*107*	133	. .	20.08	. .	. .
44	. .	. .	. .	. .	. . .	20 31.3	+89 58.0	73	*94*	119	. .	20.30	. .	. .
45	. .	. .	. .	. .	. . .	20 48.1	+89 57.5	100	*111*	149	. .	20.60	. .	. .
46	. .	. .	. .	. .	. . .	7 34.4	+89 58.9	*27*	59	65	. .	20.96	. .	. .

TABLE II.

THE NORTH POLAR SEQUENCE OF RED STARS.

Des.	H.R.	18	48	Greenwich.	DM.	R.A. 1900.	Dec. 1900.	x	y	N.P.D.	Ptm.	Ptg.	Diff.	Sp.
						h. m.	° ′	″	″	″				
1r	2609	*95*	. .	39d	+87° 51	6 53.7	+87 12.3	*2331*	9786	10060	5.26	6.69	1.43	K 5
2r	7394	728	. .	401k	+88° 112	19 22.5	+88 59.3	1282	*3411*	3644	6.55	7.73	1.18	Ma
3r	. .	*80*	. .	101g	+88° 76	13 4.5	+88 11.2	*6271*	*1810*	6528	7.57	8.62	1.05	K
4r	. .	. .	. .	364k	+88° 114	19 43.3	+88 41.1	2060	*4262*	4733	8.26	8.97	0.71	K
5r	. .	. .	. .	170g	+89° 22	12 51.5	+88 54.1	*3853*	*882*	3953	8.67	9.78	1.11	K
6r	. .	431	211	114P	+89° 9	6 38.9	+89 28.1	*324*	1885	1914	9.25	10.17	0.92	G 5
7r	. .	408	184	122P	+89° 35	15 55.1	+89 46.2	*429*	*708*	828	9.84	10.57	0.73	G2?
8r	. .	412	195	124P	+89° 31	16 49.3	+89 38.6	*388*	*1221*	1281	10.39	11.06	0.67	G5?
9r	. .	290	67	83P	. . .	14 51.2	+89 34.2	*1132*	*1046*	1541	10.90	11.56	0.66	. .
10r	. .	308	85	97P	. . .	13 8.0	+89 42.7	*993*	*303*	1038	. .	12.21	. .	. .
11r	. .	436	219	119P	. . .	14 58.4	+89 53.3	*286*	*282*	402	12.24	12.83	0.59	. .
12r	. .	514	300	. .	. . .	19 3.6	+89 52.1	130	*458*	474	. .	13.34	. .	. .



STANDARD NORTH POLAR SEQUENCE

TABLE III.

SUPPLEMENTARY STANDARD STARS NEAR THE NORTH POLE.

Des.	H.R.	18	48	Greenwich.	DM.	R.A. 1900.	Dec. 1900.	x	y	N.P.D.	Ptm.	Ptg.	Diff.	Sp.
						h. m.	° ′	″	″	″				
1s	424	..	..	152a	+88° 8	1 22.6	+88 46.4	4131	1553	4414	2.12	2.71	0.59	F 8
2s	4686	..	..	212f	+88° 71	12 14.4	+88 15.3	*6273*	*395*	6285	6.28	6.38	0.10	A 5
3s	4683	*70*	..	7g	+87° 107	12 13.9	+86 59.5	*10810*	*661*	10830	6.33	6.54	0.21	F
4s	..	303	80	93P	+89° 12	8 30.5	+89 32.2	*1017*	1319	1666	9.58	9.99	0.41	G
5s	..	441	227	121P	+89° 37	15 29.3	+89 52.8	*262*	*340*	432	9.86	10.68	0.82	G5?
6s	..	297	75	96P	+89° 26	12 53.2	+89 41.7	*1065*	*252*	1098	10.75	10.97	0.22	..
7s	..	440	225	120P	...	15 24.0	+89 53.0	*266*	*328*	420	..	12.31	..	..
8s	..	411	191	..	...	13 2.8	+89 53.0	*402*	*113*	420	..	14.06	..	..
9s	..	478	265	..	...	11 56.0	+89 58.5	*87*	2	90	13.94	14.33	0.39	..
10s	..	532	323	..	...	3 23.3	+89 54.5	208	255	329	..	14.88	..	..
11s	..	466	254	..	...	16 13.4	+89 55.1	*132*	*263*	294	..	14.91	..	..
12s	..	579	365	..	...	23 32.5	+89 53.3	398	*48*	401	..	14.97	..	..
13s	..	..	339	..	...	3 9.4	+89 53.3	272	295	401	..	15.09	..	..
14s	..	..	363	..	...	0 18.4	+89 53.6	385	31	386	..	15.61	..	..
15s	..	..	259	..	...	14 13.6	+89 57.5	*123*	*81*	147	..	16.28	..	..
16s	..	..	337	..	...	22 20.4	+89 55.1	264	*122*	292	..	16.58	..	..
17s	..	..	..	..	...	15 43.4	+89 54.2	*194*	*286*	346	..	16.97	..	..
18s	..	..	..	..	...	14 28.8	+89 57.7	*112*	*85*	141	..	17.86	..	..
19s	..	..	..	..	...	16 4.7	+89 54.7	*153*	*278*	317	..	18.30	..	..
20s	..	..	..	..	...	2 46.4	+89 57.4	116	103	155	..	18.56	..	..
21s	..	..	..	..	...	15 46.4	+89 55.3	*155*	*235*	282	..	18.67	..	..
22s	..	..	..	..	...	21 18.1	+89 56.9	143	*122*	188	..	18.75	..	..
23s	..	..	..	..	...	14 32.0	+89 57.3	*128*	*100*	162	..	18.88	..	..
24s	..	..	..	..	...	11 16.6	+89 57.5	*146*	28	149	..	18.88	..	..
25s	..	..	..	..	...	2 45.3	+89 58.1	86	73	113	..	19.02	..	..
26s	..	..	..	..	...	3 55.6	+89 57.4	82	136	159	..	19.29	..	..
27s	..	..	..	..	...	12 26.1	+89 57.7	*140*	*16*	141	..	19.30	..	..
28s	..	..	..	..	...	2 36.2	+89 57.3	127	103	164	..	19.56	..	..
29s	..	..	..	..	...	23 32.8	+89 57.8	134	*16*	135	..	20.04	..	..
30s	..	..	..	..	...	20 6.7	+89 57.9	66	*107*	126	..	20.18	..	..
31s	..	..	..	..	...	8 23.6	+89 57.6	*84*	116	143	..	20.18	..	..
32s	..	..	..	..	...	19 2.4	+89 58.8	19	*68*	71	..	20.18	..	..
33s	..	..	..	..	...	18 0.0	+89 59.5	0	*32*	32	..	20.24	..	..
34s	..	..	..	..	...	12 18.6	+89 57.7	*135*	*11*	135	..	20.30	..	..
35s	..	..	..	..	...	9 26.8	+89 59.2	*38*	30	48	..	20.46	..	..
36s	..	..	..	..	...	9 12.4	+89 58.3	*78*	70	105	..	20.56	..	..
37s	..	..	..	..	...	22 7.4	+89 58.4	86	*46*	98	..	20.58	..	..
38s	..	..	..	..	...	12 21.6	+89 57.5	*148*	*14*	149	..	21.00	..	..

The accompanying Plate shows the stars in the vicinity of the North Pole on a scale of 5″ = 1mm. The original negative was taken with the 60-inch Mt. Wilson Telescope, with an exposure of 240^m. The numbers are the same as those in the first column of the tables.

PERIODS OF 22 VARIABLE STARS.

SYSTEMATIC observations of the majority of the variables recently discovered on photographs belonging to the Harvard Map of the Sky have been delayed, on account of the difficulty of determining their magnitudes on an absolute scale. The adoption of magnitudes for the stars in the Polar Sequence, as described above, is an important step toward the solution of this problem. Estimates of the brightness of nearly all the variables announced in Circular 122, together with the brighter objects announced in Circulars 79 and 115, were, however, made on a large number of plates, soon after their discovery. Nine of them, which were found to be of the Algol type, or closely related to it, were discussed in H.A. 60, No. 4. The periods of the others, so far as they have been determined, are given in Table IV. Many of the observations were made by Miss A. D. Walker, who also determined the periods of *104758*, *105863*, *110060*, and *113662*. The observations of *132763* and *134459* were made, and their periods determined by Miss Margaret Harwood and Miss Frances Lowater, respectively. In Table IV, the first two columns give the designation and Harvard number. The third column gives the zone number, taken from the Cape Photographic Durchmusterung, except in the cases of *110551* and *121548*, for which it is taken from the Cordova Durchmusterung. When a name has been assigned by the Committee of the Astronomische Gesellschaft, it is given in the Remarks which follow the Table. The fourth and fifth columns give the right ascension and declination for 1900. The magnitudes at maximum and at minimum, as read from the light curve, are given in the sixth and seventh columns. These magnitudes are on a provisional scale, which may not be quite uniform for the different variables. The length of the period, expressed in days, is contained in the eighth column. The ninth column gives the epoch of maximum, or of minimum when the variable is of class V, expressed in days following J. D. 2,410,000. The number of days required for the light to increase from minimum to maximum, the number of periods which elapsed between the earliest and latest plates observed, and the number of plates, are contained in the tenth, eleventh, and twelfth columns. The earliest plates observed for the variables *092673*, *105364*, *105863*, and *110551*, were taken in 1890, while for the remaining variables the earliest plates were taken in 1889. The thirteenth and fourteenth columns give the type of variation, according to the revised classification proposed in Circular 166, and the class of spectrum. The spectra of variables *104455*, *110551*, and *134459*, were classified by Mrs. Fleming, the others by Miss Cannon. The last column contains the initial of the observer, the letters H, L, Lo, and W, referring to Miss Harwood, Miss Leavitt, Miss Lowater, and Miss Walker, respectively.

TABLE IV.

PERIODS OF 22 VARIABLE STARS.

Des.	H.	DM.	R.A. 1900.			Dec. 1900.		Max.	Min.	Period.	Epoch.	M−m	Periods.	Plates.	Cl.	Sp.	Obs.
			h.	m.	s.	°	′			d	d	d					
092673	1269	..	9	26	29	−73	6.3	9.0	12.0	202	150	95	29	251	II	K	L
102359	1272	2135	10	23	14	−59	9.7	9.1	10.0	5.3458	1.7	0.9	1200	258	IV	G	L
102458	1216	2234	10	24	38	−58	50.3	9.0	10.7	18.158	9.5	5	354	280	IV	G 5	L
102557	1273	*3425*	10	25	26	−57	6.2	8.1	9.1	3.6822	0.1	0.6	1743	290	IV	F 2	L
102861	1274	1705	10	28	30	−61	16.1	8.7	10.0	5.5437	4.9	1.3	1122	58	IV	G	W
103260	1220	2033	10	32	38	−60	29.5	9.4	10.3	5.2047	1.0	1.4	1233	290	IV	G	L
*104057*a	1224	*3737*	10	40	36	−57	2.6	7.8	9.2	18.984	9.5	6	367	396	IV	G 0	L
104055	1275	3800	10	40	54	−55	45.8	8.8	10.8	14.097	2.7	4	444	434	IV	K	L
104758	1228	2797	10	47	37	−58	51.3	9.6	10.7	4.676	3.5	1.2	1337	56	IV	F	W
105160	808	2386	10	51	20	−60	24.3	8.3	10.2	23.00	21.9	3	272	53	IV	F 8	W
105364	1277	1564	10	53	22	−64	35.9	8.8	10.1	15.725	14.1	3	375	58	IV	G 5	W
105863	1278	1798	10	58	19	−63	43.4	9.2	10.7	12.434	3.4	6.0	473	58	IV	K	W
110060	1279	2497	11	0	7	−60	26.3	8.6	10.7	16.644	1.0	6.5	375	57	IV	..	W
110551	1281	5387	11	5	29	−51	56.9	10.1	10.7	3.1508	0.98	0.2	2475	239	V	A	L
113657	1285	..	11	36	10	−57	6.3	9.6	<13.0	278	145	..	22	110	II	..	W
113662	1286	2223	11	36	14	−62	8.4	8.8	10.5	3.3345	3.2	1.0	1768	58	IV	G 0	W
114161	1288	..	11	41	42	−61	20.2	10.2	<14.0	199	160	..	32	485	II	..	W
120658	1292	4151	12	6	42	−58	13.6	8.9	9.5	198.5	158	14	41	441	V	Gp	L
121548	1295	7357	12	15	52	−48	39.3	8.6	10.3	16.50	9	5	467	285	IV	F 8	L
123753	1297	5293	12	37	37	−53	58.8	10.0	<16.0	Irr. ?	..	..	..	273	II?	K	W
132763	1300	..	13	27	6	−63	32.4	9.0	11.2	15.037	12.3	3	462	103	IV	..	H
134459	1304	5228	13	44	21	−59	54.7	9.5	12.0	298	180	140	22	258	II	Md?	Lo

REMARKS.

102359. The decrease from maximum to minimum occupies about $2^{d}.4$, and the light remains nearly stationary at minimum for about $2^{d}.0$.

102557. The decrease from maximum to minimum occupies about $1^{d}.7$, and the light remains nearly stationary at minimum for about $1^{d}.2$. The spectrum is possibly of class F 2 when the variable is near maximum, and G when it is faint, although such a change is not fully verified.

104055. There is probably a pause in the decrease of light, beginning about $2^{d}.5$ after maximum, and continuing for about a day. The spectrum is classified by Miss Cannon as G 5.

105160. The duration of maximum is extremely short, and the rise from minimum to maximum occupies only 3 days, or a little more than one eighth of the entire period.

105364. The decrease from maximum to minimum occupies about 7 days, and the light remains nearly stationary at minimum for about 4 days.

110551. ST Centauri. The period is divided by two minima of unequal depth. Observation was difficult, as the image is near the edge on the greater number of plates, but it seems to be certain, that at some minima the variable is not fainter than the magnitude 10.4, while on several plates it appears to be fully as faint as the magnitude 10.8. The brighter and fainter minima do not, however, appear to succeed each other regularly. In order to study the nature of the light curve, the plates were divided into two sections, containing those taken from 1890 to 1904, inclusive, and those taken from 1905 to 1911. They were then arranged in groups of 5, in the order of phases, and the means taken for each group. The resulting curves are fairly smooth. During the years 1890 to 1904, the first minimum had the mean magnitude 10.50, and was followed after an interval of $1^d.68$, or more than half the full period, by a minimum having the mean magnitude 10.68. During the years 1905 to 1911, the first minimum, magnitude 10.66, was followed after an interval of $1^d.54$, or slightly less than half the full period, by a minimum of 10.60. There seems, therefore, to be some evidence that there was a change in the order of high and low minima about 1904. The large residuals for individual plates, however, indicate that such changes may be frequent. At both minima, the decrease and increase of light each occupy about $0^d.20$ and the light apparently remains constant at minimum for about $0^d.25$. It is uncertain whether the light remains constant at maximum. It would be of great interest to keep this variable under constant observation for several weeks. As the minima are separated by an interval of about a day and a half, it is not usually possible to observe tham successively, but the phases are repeated about once a month.

113657. UV Centauri. The form of the light curve, near minimum, is not determined by the observations.

114161. See Remark on *113657*.

120658. W Crucis. The light curve resembles that of β Lyrae, and the period is longer than any other of this type as yet known. The spectrum was found by Mrs. Fleming to contain several bright lines. At the principal minimum, the magnitude is 9.52, and the duration of the total phase is 14.8 days. The increase and decrease of light each occupy about 14 days. The magnitude at the maximum following the principal minimum is 8.88, at secondary minimum 9.18, and at the second maximum 8.92. There appears to be no doubt of the difference of 0.04 magnitudes between the first and second maxima. In a paper read before the Astronomical and Astrophysical Society of America in December, 1911, Professor H. N. Russell of Princeton University has given elements of the system which satisfy the observations with remarkable closeness. He shows that the densities of the two eclipsing bodies cannot exceed $\frac{1}{170,000}$ and $\frac{1}{11,000}$ that of the Sun, respectively, and calls attention to the contrast between this variable and W Ursae Majoris which is also of the type of β Lyrae, with a spectrum of Class G, but has a period of only 8 hours.

121548. SX Centauri. The magnitudes of this variable are not the same at different maxima and minima. The light-curve usually has one of two forms, — having maxima at about 8.7, and 9.0, respectively, and corresponding minima at about 10.0, and 10.3, respectively. When the observations of a single year are considered, one type of curve is usually found to predominate. Bright and faint maxima occasionally follow each other, however, though apparently not in any regular order. There is a still-stand, or more probably a partial recovery of brightness, between 3 and 5 days after maximum. Although the magnitudes at maxima and minima vary, the period seems to have been fairly constant since 1895. Occasional irregularities of 2 or 3 days have been observed, however, and are probably real. The observations between 1889 and 1895 would be better satisfied by assuming a period of 16.55 days.

123753. UW Centauri. This variable is, perhaps, of the rare type exemplified by R Coronae, in which the light remains constantly near maximum for long periods, but declines greatly at times which do not appear to be connected with any regular period. On 84 plates taken between March 26, 1901 and January 9, 1904, the brightness varies only between the magnitudes 10.0 and 10.6. On January 9, 1904 the magnitude was 10.15, on February 3 it was 12.15, and on April 16, it was 14.70. A still more rapid decrease in light took place in 1897. Observations on 11 plates taken between January 5 and May 29 ranged from magn. 11.0 to 11.3. On May 29, the magnitude was 11.00 on June 9, 12.05, on July 1, 12.90, and on July 22, it was not seen, and was fainter than 16. At times fluctuations of light have been observed, with a range of one or two magnitudes, and covering a period of two or three months.

132763. The decline from maximum to minimum occupies about 6 days, and the light remains nearly stationary at minimum for about 5 days. There appears to be a decrease in the rate of the decline of light beginning about 2 days after maximum, and continuing for about 2 days.

EDWARD C. PICKERING.

February 21, 1912.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 171.

FIVE VARIABLE STARS HAVING SECONDARY MINIMA.

THE light curves of variable stars of the β Lyrae type, or of the Algol type having secondary minima are of especial interest, since they furnish the means of determining the dimensions and form of orbit of these systems. Observations of several of these objects have been made by Professor O. C. Wendell with the 15-inch Equatorial of this Observatory, using the photometer with achromatic prisms. The observations of U Scuti preceding 1903, will be found in H.A. 69, Part 1. As many observations have been made since then, Professor Wendell has determined the light curves of five of these objects with the results given below. The successive columns of Table I give the designation, the name of the variable, the assumed epoch and period, the number of observations, the Durchmusterung number, and assumed photometric magnitude of the star with which the variable was compared.

TABLE I.

ELEMENTS OF VARIABLES.

Des.	Name.	Epoch.	Period.	No.	DM.	Magn.
			d.			
031646	RT Persei	2416741.2431	0.849421	115	+46° 739	9.70
172907	RV Ophiuchi	2416604.7396	3.6872	50	+ 7° 3399	9.06
181115	V Serpentis	2410002.677	3.45348	87	−15° 4908	9.04
182158	RZ Draconis	2417674.348	0.55088	111	+58° 1806	8.64
184812	U Scuti	2415651.041	0.9545	73	−12° 5198	9.34

The observations of the Algol variables R Canis Majoris and Z Herculis, contained in H.A. 69, Part I, also show well marked secondary minima.

The corresponding phases and magnitudes are given in Table II. Points are given for every twenty-fourth part of the period, and when the light is changing rapidly, at shorter intervals.

TABLE II.

LIGHT CURVES OF VARIABLES.

RT Persei.		RV Ophiuchi.		V Serpentis.		RZ Draconis.		U Scuti.	
Phase.	Magn.	Phase.	Magn.	Phase.	Magn.	Phase.	Magn.	Phase.	Magn.
0.000	12.04	0.000	10.72	0.000	10.41	0.000	10.77	0.000	10.65
0.007	11.86	0.031	10.36	0.029	10.45	0.005	10.72	0.008	10.57
0.014	11.69	0.061	10.07	0.058	10.38	0.009	10.67	0.016	10.43
0.021	11.50	0.092	9.83	0.086	10.20	0.014	10.61	0.024	10.31
0.028	11.33	0.123	9.64	0.115	10.03	0.018	10.53	0.032	10.21
0.035	11.17	0.154	9.53	0.144	9.91	0.023	10.46	0.040	10.12
0.042	11.04	0.184	9.48	0.173	9.83	0.028	10.37	0.048	10.04
0.050	10.89	0.215	9.49	0.201	9.77	0.032	10.31	0.056	9.96
0.057	10.79	0.246	9.51	0.230	9.72	0.037	10.24	0.064	9.90
0.064	10.75	0.277	9.53	0.259	9.69	0.041	10.20	0.072	9.84
0.071	10.74	0.307	9.54	0.288	9.66	0.046	10.14	0.080	9.79
0.078	10.74	0.338	9.54	0.317	9.63	0.069	10.06	0.119	9.72
0.106	10.74	0.461	9.51	0.432	9.58	0.092	10.01	0.159	9.67
0.142	10.74	0.615	9.49	0.576	9.53	0.115	9.98	0.199	9.66
0.177	10.74	0.768	9.48	0.719	9.52	0.138	9.97	0.239	9.66
0.212	10.74	0.922	9.48	0.863	9.51	0.161	9.99	0.278	9.68
0.248	10.74	1.075	9.50	1.007	9.50	0.184	10.04	0.318	9.72
0.283	10.74	1.229	9.51	1.151	9.51	0.207	10.09	0.358	9.81
0.319	10.74	1.383	9.53	1.295	9.53	0.230	10.13	0.398	9.88
0.354	10.75	1.536	9.56	1.439	9.58	0.252	10.17	0.438	9.91
0.361	10.76	1.690	9.58	1.468	9.59	0.275	10.18	0.477	9.92
0.368	10.77	1.844	9.59	1.497	9.62	0.298	10.14	0.517	9.89
0.375	10.79	1.997	9.59	1.525	9.65	0.321	10.09	0.557	9.83
0.382	10.81	2.151	9.57	1.554	9.66	0.344	10.03	0.597	9.75
0.389	10.84	2.304	9.55	1.583	9.69	0.367	9.99	0.636	9.69
0.396	10.86	2.458	9.53	1.612	9.70	0.390	9.97	0.676	9.66
0.404	10.89	2.612	9.51	1.640	9.72	0.413	9.98	0.716	9.66
0.411	10.92	2.765	9.49	1.669	9.74	0.436	10.00	0.756	9.67
0.418	10.93	2.919	9.49	1.698	9.75	0.459	10.05	0.795	9.70
0.425	10.92	3.073	9.50	1.727	9.76	0.482	10.14	0.835	9.82
0.432	10.91	3.226	9.53	1.756	9.76	0.505	10.32	0.875	9.99
0.439	10.90	3.349	9.57	1.784	9.75	0.510	10.37	0.883	10.02
0.446	10.86	3.380	9.59	1.813	9.73	0.514	10.42	0.891	10.09
0.453	10.83	3.411	9.63	1.842	9.71	0.519	10.48	0.899	10.14
0.460	10.80	3.441	9.66	1.871	9.68	0.523	10.53	0.907	10.20
0.467	10.78	3.472	9.71	1.899	9.66	0.528	10.61	0.915	10.26

RT Persei.		RV Ophiuchi.		V Serpentis.		RZ Draconis.		U Scuti.	
Phase.	Magn.	Phase.	Magn.	Phase.	Magn.	Phase.	Magn.	Phase.	Magn.
0.474	10.77	3.503	9.80	1.928	9.65	0.533	10.67	0.923	10.33
0.481	10.76	3.534	9.99	1.957	9.63	0.537	10.73	0.931	10.41
0.489	10.75	3.564	10.25	1.986	9.62	0.542	10.77	0.939	10.50
0.496	10.75	3.595	10.86	2.015	9.60	0.546	10.78	0.947	10.60
0.531	10.74	3.626	10.99	2.158	9.55				
0.566	10.74	3.656	10.97	2.302	9.52				
0.602	10.74			2.446	9.51				
0.637	10.74			2.590	9.51				
0.672	10.74			2.734	9.51				
0.708	10.74			2.878	9.53				
0.743	10.74			3.022	9.55				
0.772	10.76			3.137	9.60				
0.779	10.79			3.166	9.62				
0.786	10.83			3.194	9.63				
0.793	10.89			3.223	9.65				
0.800	10.98			3.252	9.68				
0.807	11.09			3.281	9.71				
0.814	11.23			3.310	9.75				
0.821	11.39			3.338	9.79				
0.828	11.57			3.367	9.87				
0.835	11.77			3.396	9.99				
0.842	11.96			3.425	10.20				

Each observation consisted of four sets of four settings each and the average deviation from the curve as shown in H.A. 69, 95 is about ±0.037. The star RT Persei appears to be an Algol variable with well marked secondary minima. The observations show that the others given in the Table belong to the β Lyrae class.

EDWARD C. PICKERING.

February 21, 1912.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 172.

PHOTOGRAPHIC MAGNITUDES OF ASTEROIDS.

THE question is often asked by owners of small photographic telescopes, "What work can I do that is of real value to Astronomy?" In H.C. 169, the statement is made "It is probable that the photometry of the asteroids, in the future, will be studied mainly by photography as soon as a satisfactory scale of photographic magnitudes can be established for all the stars." An attempt to measure these magnitudes does not appear to have been made as yet, although it is not necessary that the scale should be determined, before valuable photographs can be obtained even with a small instrument. Images of stars of the eleventh magnitude can be photographed with exposures of an hour and an aperture of one inch, or of ten minutes with an aperture of three inches. The color of an asteroid is probably, in general, like that of the Sun, or like that of a star whose spectrum is of Class G 5. It appears from H.C. 169, that an asteroid whose magnitude is estimated as 10.0, would have a photometric magnitude 10.2. Applying a correction for the class of spectrum, the photographic magnitude would then be 11.1, but it would grow fainter with an increase in its phase angle, its distance from the Sun, and its distance from the Earth.

The average motion of an asteroid at opposition is about a quarter of a degree a day. It is necessary that the images of the asteroid should closely resemble those of the adjacent stars. This is accomplished with the apertures and exposures mentioned above, by following on a star in the usual way. Somewhat longer exposures may be made if a motion is given to the plate equal to one half that of the asteroid. The elongation will then be equally divided between the asteroid and the stars, so that the images can still be compared with accuracy. For faint asteroids, two exposures of equal length may be made, giving a motion to the plate during one, equal to the motion of the asteroid. The stars will appear as dots on the first exposure and the asteroid as a dot on the second. The Berliner Jahrbuch, or the reprint of the portion of it relating to asteroids, is indispensable for finding any but the brightest asteroids. The Jahrbuch for 1914 gives four positions of each of the asteroids, at intervals of ten days near opposition. The British Nautical Almanac gives the positions of the four brightest asteroids throughout the year. To find an asteroid, a photograph may be taken with long exposure, so that the asteroid may be recognized by its trail. Or, two photographs may be taken with an interval between them. Superposing the plates, the asteroid is detected by its motion. If a contact print is made of the first negative and the second negative superposed on it, each star will appear as a black point superposed upon a white circle. The asteroid will appear as a black point on one negative, and as a white circle on the other, at a distance equal to the motion of the asteroid in the interval. Once found, the asteroid can generally be followed without difficulty, if its daily motion is known. It is well to mark it by an ink circle on the back of the plate. The photographic brightness may be determined by comparing it with several adjacent stars by Argelander's method, taking care that some are slightly brighter and others slightly fainter than the asteroid. These stars should next be identified by means of the maps and catalogue of the Bonn Durchmusterung. The positions of fainter stars should be found by measuring their coordinates from the nearest Durchmusterung stars. This is generally as far as the amateur astronomer is likely to go. A series of such photographs, following the asteroid as long as it can be photographed, would have great value either with, or without the subsequent measures.

One way to determine the absolute photographic magnitudes of the comparison stars is to photograph successively on the same plate the given region and the North Pole, as described in H.C. 125 and read off the magnitudes using those given in H.C. 170. The problem is not as simple, however, as it appears, and many serious sources of error must be avoided.

Table I, which is extracted from the Berliner Jahrbuch, gives a list of the asteroids which come to opposition, between January 19, 1912 and February 8, 1913, inclusive, and attain a magnitude of 10.0, or brighter. The first four columns give the number of the asteroid, its name, its magnitude at opposition and its magnitude at mean opposition, m_0. The former minus the latter is given in the fifth column. A negative sign therefore indicates that the asteroid is this year unusually bright. The date of opposition is given in the sixth column and the first of the four dates of the ephemeris given in the Jahrbuch with the corresponding right ascension and declination are given in the three following columns. The two final columns give the right ascension and declination on a date ten days later.

TABLE I.

BRIGHT ASTEROIDS.

No.	Name.	Magn.	m_0	Diff.	Opp.	Date.	R. A.	Dec.	R A.	Dec.
							h. m.	° ′	h. m.	° ′
1	Ceres	7.0	7.4	−0.4	Jan. 19	Jan. 12	8 11.6	+30 7	8 1.7	+31 12
4	Vesta	6.6	6.5	+0.1	Feb. 18	Feb. 11	10 13.8	+19 39	10 4.1	+20 59
372	Palma	9.7	10.5	−0.8	Feb. 20	Feb. 11	10 22.7	+ 9 17	10 11.1	+ 8 46
354	Eleonora	9.3	10.0	−0.7	Feb. 22	Feb. 21	10 18.3	+16 33	10 11.1	+18 36
27	Euterpe	9.1	9.7	−0.6	Feb. 22	Feb. 15	10 27.4	+12 21	10 17.5	+13 23
7	Iris	9.2	8.4	+0.8	Mar. 22	Mar. 17	12 12.5	−10 24	12 3.1	− 9 20
39	Laetitia	9.9	9.5	+0.4	May 2	April 21	14 49.0	− 2 14	14 41.2	− 1 16
695	[1909 *J B*]	9.0	9.2	−0.2	June 1	May 31	16 39.2	+17 12	16 28.5	+15 52
21	Lutetia	9.7	10.1	−0.4	June 1	May 24	16 47.0	−21 16	16 36.8	−21 12
93	Minerva	10.0	10.8	−0.8	June 2	May 31	16 43.3	−36 6	16 32.8	−36 4
3	Juno	9.8	8.7	+1.1	June 10	May 31	17 18.5	− 4 31	17 10.1	− 4 13
70	Panopaea	10.0	10.9	−0.9	June 12	June 10	17 27.6	−34 54	17 16.3	−35 44
85	Io	10.0	10.9	−0.9	June 27	June 20	18 30.9	− 3 18	18 22.4	− 2 53
29	Amphitrite	9.4	9.0	+0.4	June 30	June 20	18 48.3	−32 34	18 37.7	−32 44
88	Thisbe	9.8	10.8	−1.0	July 14	July 10	19 40.8	−19 12	19 31.5	−19 6
41	Daphne	9.5	10.5	−1.0	July 26	July 20	20 28.6	+ 3 2	20 20.5	+ 1 50
103	Hera	9.7	10.2	−0.5	July 28	July 20	20 35.8	−16 31	20 27.5	−17 25
393	Lampetia	8.8	11.0	−2.2	Aug. 1	July 30	20 48.3	+14 6	20 42.6	+13 21
11	Parthenope	8.6	9.3	−0.7	Aug. 7	July 30	21 17.1	−16 52	21 8.5	−18 0
110	Lydia	10.0	10.5	−0.5	Aug. 19	Aug. 9	22 3.7	−22 27	21 55.1	−23 16
33	Polyhymnia	9.3	11.8	−2.5	Sept. 3	Aug. 29	22 52.6	− 9 26	22 45.9	− 9 49
10	Hygiea	9.7	9.5	+0.2	Sept. 11	Sept. 8	23 15.9	+ 0 36	23 8.6	− 0 8
8	Flora	8.1	8.9	−0.8	Sept. 12	Sept. 12	23 21.2	−15 18	23 12.9	−16 24
9	Metis	9.4	8.9	+0.5	Oct. 13	Oct. 10	1 20.1	− 0 8	1 10.4	− 0 40
20	Massalia	8.8	9.2	−0.4	Oct. 20	Oct. 18	1 45.3	+10 53	1 35.8	+ 9 55
185	Eunike	9.8	10.0	−0.2	Oct. 21	Oct. 18	1 49.1	−19 48	1 41.9	−21 8
13	Egeria	9.7	9.7	0.0	Oct. 25	Oct. 8	2 16.0	+ 5 25	2 5.8	+ 5 28
324	Bamberga	7.6	9.9	−2.3	Oct. 27	Oct. 18	2 14.9	+36 30	2 5.1	+36 45
15	Eunomia	7.4	8.6	−1.2	Oct. 31	Oct. 13	2 40.4	+36 39	2 32.0	+36 28
471	Papagena	8.5	10.1	−1.6	Nov. 5	Oct. 28	2 49.3	− 4 30	2 39.7	− 4 6
40	Harmonia	9.0	9.2	−0.2	Nov. 13	Nov. 8	3 20.7	+12 45	3 9.9	+12 23
6	Hebe	7.4	8.5	−1.1	Nov. 17	Nov. 7	3 39.7	− 9 51	3 30.7	−10 8
49	Pales	9.8	11.0	−1.2	Dec. 3	Nov. 27	4 53.2	+25 48	4 43.9	+25 21
64	Angelina	9.9	10.5	−0.6	Dec. 7	Dec. 7	5 0.0	+24 34	4 49.7	+24 14
349	Dembowska	9.5	9.8	−0.3	Dec. 7	Nov. 27	5 5.9	+31 12	4 55.6	+31 24
115	Thyra	9.4	10.4	−1.0	Dec. 22	Dec. 17	6 9.5	+38 5	5 56.5	+36 54
18	Melpomene	9.2	9.3	−0.1	Jan. 39	Dec. 32	7 28.8	+ 9 24	7 18.0	+10 28

Another extremely useful piece of work would be the determination of the positions of the asteroids which have not been seen for several years. Of the 739 asteroids whose elements have been computed, 38 have not been seen since 1904, and 6 since 1891. A list of these is contained in Table II which gives the year of the last observation, the number of the asteroid, its name, its magnitude at this opposition, its magnitude at mean opposition, the difference, the date of opposition and the year of discovery.

TABLE II.

ASTEROIDS NOT RECENTLY OBSERVED.

Year.	No.	Name.	Magn.	m_0	Diff.	Opp.	Disc.
1890	272	Antonia	13.6	13.6	0.0	May 10	1888
"	280	Philia	14.9	14.4	+0.5	July 18	1888
"	290	Bruna	14.3	13.9	+0.4	June 7	1890
"	293	Brasilia	12.4	12.9	−0.5	Dec. 30	1890
1891	309	Fraternitas	13.1	12.7	+0.4	Mar. 4	1891
1899	180	Garumna	13.5	13.3	+0.2	Oct. 3	1878
1900	239	Adrastea	14.6	14.0	+0.6	Feb. 14	1884
"	244	Sita	14.3	13.7	+0.6	May 11	1884
"	262	Valda	13.6	14.1	−0.5	Feb. 13	1886
"	459	Signe	14.2	13.7	+0.5	July 4	1900
"	461	Saskia	13.1	14.3	−1.2	Dec. 34	1900
1901	98	Ianthe	10.4	12.7	−2.3	Mar. 11	1868
"	141	Lumen	10.1	11.4	−1.3	Sept. 5	1875
"	201	Penelope	12.6	11.9	+0.7	Jan. 25	1879
"	464	Megaira	13.2	12.2	+1.0	April 17	1901
"	467	Laura	14.7	14.3	+0.4	April 3	1901
1902	252	Clementina	12.8	13.0	−0.2	July 6	1885
"	254	Augusta	12.9	13.4	−0.5	April 15	1886
"	265	Anna	14.3	13.8	+0.5	Dec. 43	1887
1902	296	Phaëtusa	14.0	13.3	+0.7	Mar. 5	1890
1903	81	Terpsichore	11.2	11.8	−0.6	Sept. 1	1864
"	264	Libussa	12.8	12.1	+0.7	Mar. 31	1886
"	271	Penthesilia	12.9	12.8	+0.1	June 29	1887
"	299	Thora	14.5	14.5	0.0	July 5	1890
"	327	Columbia	12.8	13.0	−0.2	Sept. 19	1892
"	343	Ostara	13.0	13.5	−0.5	Jan. 25	1892
1903	492	Gismonda	12.8	13.1	−0.3	May 29	1902
"	512	Taurinensis	13.8	12.5	+1.3	April 6	1903
1904	83	Beatrix	11.8	11.3	+0.5	Oct. 24	1865
"	204	Kallisto	12.3	12.0	+0.3	Feb. 3	1879
"	226	Weringia	13.7	13.0	+0.7	Feb. 19	1882
"	232	Russia	12.4	13.4	−1.0	May 11	1883
"	236	Honoria	12.3	11.4	+0.9	April 4	1884
"	319	Leona	14.0	14.2	−0.2	Jan. 30	1891
"	436	Patricia	13.1	12.9	+0.2	Feb. 9	1898
"	525	Adelaide	15.4	13.8	+1.6	May 14	1904
"	529	Preziosa	12.5	13.0	−0.5	Nov. 20	1904

A negative sign in the sixth column indicates that the asteroid is unusually bright. It therefore follows that this year will be a particularly good one for rediscovering Nos. 98, 141, 461, and 232, and that it would be a very unfavorable one for looking for 525, 512, and 464.

EDWARD C. PICKERING.

FEBRUARY 22, 1912.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 173.

PERIODS OF 25 VARIABLE STARS IN THE SMALL MAGELLANIC CLOUD.

The following statement regarding the periods of 25 variable stars in the Small Magellanic Cloud has been prepared by Miss Leavitt.

A Catalogue of 1777 variable stars in the two Magellanic Clouds is given in H.A. 60, No. 4. The measurement and discussion of these objects present problems of unusual difficulty, on account of the large area covered by the two regions, the extremely crowded distribution of the stars contained in them, the faintness of the variables, and the shortness of their periods. As many of them never become brighter than the fifteenth magnitude, while very few exceed the thirteenth magnitude at maximum, long exposures are necessary, and the number of available photographs is small. The determination of absolute magnitudes for widely separated sequences of comparison stars of this degree of faintness may not be satisfactorily completed for some time to come. With the adoption of an absolute scale of magnitudes for stars in the North Polar Sequence, however, the way is open for such a determination.

Fifty-nine of the variables in the Small Magellanic Cloud were measured in 1904, using a provisional scale of magnitudes, and the periods of seventeen of them were published in H.A. 60, No. 4, Table VI. They resemble the variables found in globular clusters, diminishing slowly in brightness, remaining near minimum for the greater part of the time, and increasing very rapidly to a brief maximum. Table I gives all the periods which have been determined thus far, 25 in number, arranged in the order of their length. The first five columns contain the Harvard Number, the brightness at maximum and at minimum as read from the light curve, the epoch expressed in days following J.D. 2,410,000, and the length of the period expressed in days. The Harvard Numbers in the first column are placed in Italics, when the period has not been published hitherto. A remarkable relation between the brightness of these variables and the length of their periods will be noticed. In H.A. 60, No. 4, attention was called to the fact that the brighter variables have the longer periods, but at that time it was felt that the number was too small to warrant the drawing of general conclusions. The periods of 8 additional variables which have been determined since that time, however, conform to the same law.

TABLE 1.

PERIODS OF VARIABLE STARS IN THE SMALL MAGELLANIC CLOUD.

H.	Max.	Min.	Epoch.	Period.	Res. *M*.	Res. *m*.
			d.	*d.*		
1505	14.8	16.1	0.02	1.25336	−0.6	−0.5
1436	14.8	16.4	0.02	1.6637	−0.3	+0.1
1446	14.8	16.4	1.38	1.7620	−0.3	+0.1
1506	15.1	16.3	1.08	1.87502	+0.1	+0.1
1413	14.7	15.6	0.35	2.17352	−0.2	−0.5
1460	14.4	15.7	0.00	2.913	−0.3	−0.1
1422	14.7	15.9	0.6	3.501	+0.2	+0.2
842	14.6	16.1	2.61	4.2897	+0.3	+0.6
1425	14.3	15.3	2.8	4.547	0.0	−0.1
1742	14.3	15.5	0.95	4.9866	+0.1	+0.2
1646	14.4	15.4	4.30	5.311	+0.3	+0.1
1649	14.3	15.2	5.05	5.323	+0.2	−0.1
1492	13.8	14.8	0.6	6.2926	−0.2	−0.4
1400	14.1	14.8	4.0	6.650	+0.2	−0.3
1355	14.0	14.8	4.8	7.483	+0.2	−0.2
1374	13.9	15.2	6.0	8.397	+0.2	−0.3
818	13.6	14.7	4.0	10.336	0.0	0.0
1610	13.4	14.6	11.0	11.645	0.0	0.0
1365	13.8	14.8	9.6	12.417	+0.4	+0.2
1351	13.4	14.4	4.0	13.08	+0.1	−0.1
827	13.4	14.3	11.6	13.47	+0.1	−0.2
822	13.6	14.6	13.0	16.75	−0.1	+0.3
823	12.2	14.1	2.9	31.94	−0.3	+0.4
824	11.4	12.8	4.	65.8	−0.4	−0.2
821	11.2	12.1	97.	127.0	−0.1	−0.4

The relation is shown graphically in Figure 1, in which the abscissas are equal to the periods, expressed in days, and the ordinates are equal to the corresponding magnitudes at maxima and at minima. The two resulting curves, one for maxima and one for minima, are surprisingly smooth, and of remarkable form. In Figure 2, the abscissas are equal to the logarithms of the periods, and the ordinates to the corresponding magnitudes, as in Figure 1. A straight line can readily be drawn among each of the two series of points corresponding to maxima and minima, thus showing that there is a simple relation between the brightness of the variables and their periods. The logarithm of the period increases by about 0.48 for each increase of one magnitude in brightness. The residuals of the maximum and minimum of each star from the lines in Figure 2 are given in the sixth and seventh columns of Table I. It is possible that the deviations from a straight line may become smaller when an absolute scale of magnitudes is used, and they may even indicate the corrections that need to be applied to the provisional scale. It should be noticed that the average range, for bright and faint variables alike, is about 1.2 magnitudes. Since the variables are probably at nearly the same distance from the Earth, their periods are apparently associated with their actual emission of light, as determined by their mass, density, and surface brightness.

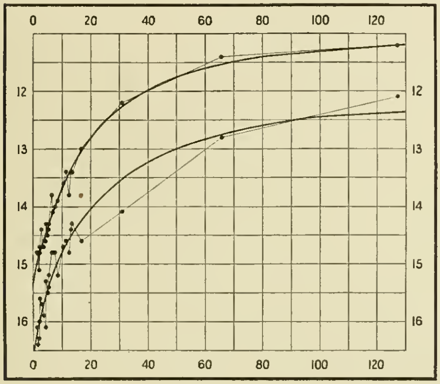


Fig. 1.

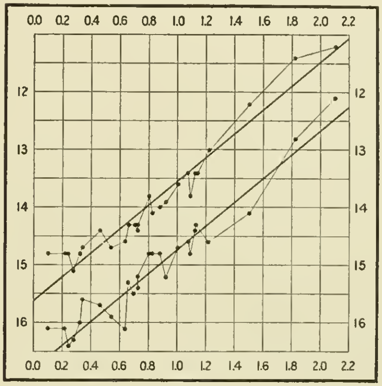


Fig. 2.

The faintness of the variables in the Magellanic Clouds seems to preclude the study of their spectra, with our present facilities. A number of brighter variables have similar light curves, as UY Cygni, and should repay careful study. The class of spectrum ought to be determined for as many such objects as possible. It is to be hoped, also, that the parallaxes of some variables of this type may be measured. Two fundamental questions upon which light may be thrown by such inquiries are whether there are definite limits to the mass of variable stars of the cluster type, and if the spectra of such variables having long periods differ from those of variables whose periods are short.

The facts known with regard to these 25 variables suggest many other questions with regard to distribution, relations to star clusters and nebulae, differences in the forms of the light curves, and the extreme range of the length of the periods. It is hoped that a systematic study of the light changes of all the variables, nearly two thousand in number, in the two Magellanic Clouds may soon be undertaken at this Observatory.

EDWARD C. PICKERING.

March 3, 1912.

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HARVARD COLLEGE OBSERVATORY.

CIRCULAR 174.

VARIABILITY OF THE POLE STAR.

THE variability of the Pole Star was announced by Dr. Hertzsprung in the Astron. Nach. 189, 89 and confirmed successively by Mr. Edward S. King (Science 34, 523, and H.A. 59, 249), and by Professor Joel Stebbins in a paper presented to the Astronomical and Astrophysical Society of America in December, 1911. The period, $3^{d}.9683$, found for it as a spectroscopic binary, is also apparently the period of its variation. It, accordingly, appeared advisable to see if this result was confirmed by the observations made at this Observatory from 1879 to 1882, in connection with the Harvard Photometry, and published in H.A. 14, 13. The instrument employed was the 2-inch Meridian Photometer, and the two images of the Pole Star were usually compared at the beginning, middle, and end of each series. One hundred stars of about the fourth magnitude, and in declination between +58° and +76° were selected as standards. Several of these were observed in each series. Since all of the observations were reduced by means of the measures of the Pole Star, it is evident that if the latter was brighter than usual on any night the standard stars would measure faint and would give positive residuals. From the columns headed mean residuals in Table III in H.A. 14, 35, it was concluded that the Pole Star did not undergo any variation of long period. The average value of the residuals in these columns is ±0.02, although the individual observations were only reduced to tenths of a magnitude. A grouping has now been made of the residuals in the tenth column of Table II of H.A. 14, 13. The first seventy series were omitted, since the constants were assumed for these dates. The phase for the middle of each series has been computed by the formula, J.D. 2,400,000 + 3.9683 E. Ten groups were formed extending over the intervals $0^{d}.0$ to $0^{d}.4$, $0^{d}.4$ to $0^{d}.8$, etc. The results are given in Table I. The centre of each group is given in the first column. The next twelve columns give the numbers of the residuals for each and for all of the observers, the corresponding algebraic sums, and the means of the residuals.

TABLE I.

GROUPING OF RESIDUALS.

Ph.	Numbers.				Sums.				Means.			
	P.	S.	W.	All.	P.	S.	W.	All.	P.	S.	W.	All.
d.												
0.2	68	27	25	120	−33	+31	+ 9	+ 7	−.05	+.11	+.04	+.01
0.6	74	69	54	197	−34	−55	−22	−111	−.05	−.08	−.04	−.06
1.0	47	60	45	152	−17	− 4	− 2	− 23	−.04	−.01	.00	−.02
1.4	42	38	46	126	+ 1	−12	− 5	− 16	.00	−.03	−.01	−.01
1.8	52	38	36	126	+48	+36	+29	+113	+.09	+.11	+.08	+.09
2.2	43	58	22	123	+10	+19	+ 9	+ 38	+.02	+.03	+.04	+.03
2.6	61	64	54	179	+31	+11	+13	+ 55	+.05	+.02	+.02	+.03
3.0	69	45	54	168	+ 4	+ 2	− 9	− 3	+.01	.00	+.02	.00
3.4	63	53	53	169	+ 1	−42	−14	− 55	.00	−.08	−.10	−.03
3.8	57	43	50	150	+ 4	−19	−18	− 33	+.01	−.04	−.07	−.02

The quantities to be determined are so small that the last of these columns only gives satisfactory results, although it will be noticed that the signs are negative for all three of the observers in the second and third groups, and positive in the fifth, sixth, and seventh groups. The light curve, or relation of the first and last columns of Table I, is shown in Figure 1. It appears that the maximum light corresponds to a phase of 2.0 days. The observations were nearly continuous from February 2, 1880, to September 17, 1882, or J.D. 2,407,748 to 2,408,706. The middle of this period is 2,408,227. We may therefore assume that a maximum occurred on 2,408,229.0, and that the probable error does not exceed $\pm 0^d.3$. As nearly three thousand periods have elapsed since then, a comparison of this result with that derived from observations made at the present time should determine the period with a probable error not greatly exceeding a ten thousandth of a day. Its principal value, however, would be to ascertain whether any change has taken place in the period during the last thirty years.

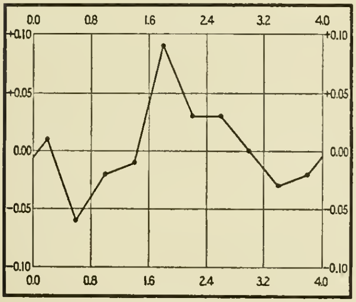


Fig. 1.

EDWARD C. PICKERING.

April 8, 1912.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 175.

PHOTOMETRIC MEASUREMENTS OF NOVA GEMINORUM, No. 2.

PHOTOMETRIC measurements of Nova Geminorum, No. 2, and of a sequence of comparison stars were made by Professor O. C. Wendell, with the photometer with achromatic prisms attached to the 15-inch East Equatorial. The comparison stars were selected from photographic plates and accordingly the intervals between the successive stars will be more nearly uniform when expressed in photographic, rather than in photometric, magnitudes. The extension of this sequence to much fainter stars, and their photographic magnitudes, will be made the subject of another Circular. The stars measured photometrically are given in Table I. The first column gives the number, in the order of photographic brightness, and, therefore, is not the same as the order of photometric brightness. The number in Table IV of Monthly Notices, 72, 303, the number in the Revised Harvard Photometry, the number in the Bonn Durchmusterung, the right ascension for 1900, and the declination for 1900, are given in the next five columns. The photometric magnitude is given in the seventh column; for stars 1 to 9, it is taken from H.A. 50, for stars 10 to 13 from H.A. 54, and for the other stars it is derived from the measures of Professor Wendell. The number of the star in the sequence with which each star was compared is given in the eighth column, and the residuals from the mean for each night, in the ninth. Each star was measured on two nights. Four sets of four settings each were made on each night. The first and second residuals, accordingly, are always opposite in sign, and are either equal, or differ by one hundredth of a magnitude. The class of spectrum is given in the tenth column, and the photographic magnitude derived from the photometric magnitude and class of spectrum, in the eleventh.

The photometer with achromatic prisms is only capable of comparing stars whose distance apart does not exceed 35′. As is shown in Table I, the greater

TABLE I.

COMPARISON STARS.

No.	M. N.	H. R.	B. D.	R. A. 1900.		Dec. 1900.		Ptm.	St.	Res.	Sp.	Ptg.
				h.	m.	°	′					
N	. .	. .	. .	6	48.4	+32	16	. .	. .	. .	. .	. .
1	. .	2095	+37° 1380	5	52.9	+37	12	2.71	. .	. .	A 0 p	2.71
3	. .	2473	+25° 1406	6	37.8	+25	14	3.18	. .	. .	G 5	4.09
2	. .	2540	+34° 1481	6	46.2	+34	5	3.64	. .	. .	A 2	3.71
6	. .	2821	+28° 1385	7	19.5	+28	0	3.89	. .	. .	K 0	5.06
4	. .	2852	+32° 1562	7	22.7	+31	59	4.18	. .	. .	F 0	4.50
5	. .	2398	+28° 1168	6	29.0	+28	6	5.05	. .	. .	A 0	5.05
7	. .	2425	+29° 1293	6	32.1	+29	4	5.54	. .	. .	B 9	5.50
8	. .	2372	+32° 1324	6	26.0	+32	31	5.98	. .	. .	A 0	5.98
9	98	2620	+32° 1460	6	54.8	+32	32	6.46	. .	. .	F 0	6.78
10	19	. .	+32° 1433	6	47.6	+32	38	6.89	. .	. .	B 9	6.85
11	. .	. .	+30° 1318	6	38.7	+30	57	7.13	. .	. .	A 0	7.13
13	. .	. .	+31° 1413	6	41.3	+31	48	7.99	. .	. .	F 8	8.62
14	89	. .	+32° 1447	6	50.6	+32	25	8.23	16	*07*,07	A 5	8.39
16	85	. .	+32° 1443	6	49.9	+32	37	8.40	10	*06*,06	G 0	9.11
17	59	. .	+31° 1442	6	48.9	+31	53	8.47	18	07,*07*	G 5	9.38
18	81	. .	+32° 1441	6	49.7	+32	1	8.78	14	04,*04*	K	9.93
15	21	. .	+32° 1434	6	47.7	+32	27	8.79	10	*04*,04	A	8.79
22	10	. .	+32° 1431	6	47.4	+32	31	9.82	10	03,*04*	K 0	10.99
19	11	. .	+32° 1432	6	47.4	+32	15	9.83	10	03,*03*	G	10.54
21	18	. .	. .	6	47.6	+32	10	10.37	17	*02*,02	G	11.07
20	40	. .	. .	6	48.2	+32	14	10.63	10	*08*,08	. .	. .
23	54	. .	. .	6	48.6	+32	5	11.00	10	*04*,05	. .	. .
24	58	. .	. .	6	48.8	+32	8	11.08	10	10,*09*	. .	. .
25	65	. .	. .	6	49.2	+32	14	11.33	10	*02*,02	. .	. .
26	13	. .	. .	6	47.5	+32	12	11.74	10	03,*03*	. .	. .

portion of the stars are compared directly with 10. Some of them, however, like 14, 18, and 17 are too distant. Accordingly, the intervals, 10 to 16, 16 to 14, 14 to 18, 18 to 17, 17 to 21, and 21 to 10 were measured and were found to be equal to −1.50, +0.17, −0.54, +0.31, −1.89, and +3.49 magn. As these intervals form a complete circle beginning and ending with star 10, the sum of the measures should be zero. It is actually +0.04 although the total interval measured is 6.94 magn. The four largest intervals were, accordingly, each changed by 0.01 magn.

The results of a comparison of the Nova with star 10 are given in Table II. The successive columns give the calendar date, the Julian Day and decimal following Greenwich Mean Noon, omitting the three left-hand figures 241, and the resulting magnitude. The latter depends on the assumption that the magnitude of star 10 is 6.89, as given in H.A. 54, 77. As this depends on observations on only three nights, later measures may permit a small constant correction to be applied to the entire series of measures. The magnitude of this star according to the Potsdam measures is 7.22, which as the spectrum is B 9, requires a correction of −0.27 to reduce it to the Harvard scale. The resulting magnitude 6.95 agrees closely with that given above, 6.89.

TABLE II.

MEASURES OF NOVA GEMINORUM, No. 2.

Date.	Julian Day.	Magn.	Date.	Julian Day.	Magn.	Date.	Julian Day.	Magn.
1912.			1912.			1912.		
March 14	9476.526	3.77	March 23	9485.509	4.86	April 5	9498.512	5.91
	9476.533	3.47		9485.514	4.87	" 6	9499.414	6.61
	9476.540	3.37		9485.555	4.79		9499.521	6.57
" 16	9478.515	5.26	" 25	9487.510	4.91	" 8	9501.515	6.37
	9478.522	5.33		9487.514	4.91		9501.525	6.38
	9478.634	5.34	" 27	9489.509	6.19	" 10	9503.514	6.29
	9478.642	5.38		9489.514	6.15		9503.521	6.32
" 17	9479.519	5.19		9489.572	6.23	" 13	9506.510	6.52
	9479.524	5.21	" 29	9491.543	6.05		9506.516	6.45
" 19	9481.508	5.27	" 30	9492.512	5.53	" 19	9512.519	6.43
	9481.515	5.19		9492.517	5.51		9512.524	6.43
" 20	9482.507	5.44		9492.579	5.54	" 20	9513.518	6.65
	9482.514	5.55	April 3	9496.510	5.75		9513.523	6.68
	9482.540	5.50		9496.516	5.75		9513.574	6.75
	9482.595	5.60	" 4	9497.510	6.29	June 3	9557.576	7.50
" 22	9484.509	4.96		9497.515	6.17		9557.580	7.54
	9484.514	4.93		9497.634	6.31	" 5	9559.567	7.48
	9484.583	4.91	" 5	9498.506	5.90		9559.572	7.52

EDWARD C. PICKERING.

July 16, 1912.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 176.

NOVA GEMINORUM, No. 2.

THE new star which appeared in the constellation Gemini in March, 1912, is one of the most interesting objects of its kind, since its prompt discovery has permitted us to learn more of the early history of these objects, than ever before. It was discovered by Enebo, at Dombaas, Norway, on Tuesday evening, March 12, 1912, and immediately announced so that astronomers throughout the world were enabled to observe it on the following night. An examination of the photographs of the Harvard Observatory showed no sign of it on Sunday, March 10, at 13^h 22^m G. M. T., although stars as faint as the eleventh magnitude appear, as shown in Figure 1. The scale is 60″ = 1 mm. The instrument employed was a Cooke Anastigmat, the exposure was 60^m, and the scale of the original negative was about 600″ = 1 mm. This result was confirmed by a second photograph taken the same night with a Ross Zeiss lens. An examination of other earlier photographs showed a star of the fourteenth photographic magnitude, near, but apparently not identical with the Nova. A photograph taken the following night, Monday, March 11, 12^h 13^m G.M.T., shows the Nova as a star of the photographic magnitude 4.5. It is reproduced in Figure 2. This result is confirmed by a second photograph taken the same night with the Ross Zeiss lens. It therefore follows that the star appeared in the course of twenty-three hours and that during this interval the light increased at least two hundred fold and probably ten thousand fold. The star about 3 mm. to the right of the Nova is of the tenth magnitude. A number of photographs of the spectrum of the Nova were obtained on March 13, the night following the discovery, and a succession of clear evenings permitted the remarkable changes in the spectrum to be followed closely. Seventy-four photographs of the spectrum of this star have been obtained with the 8-inch Telescopes at Cambridge and Arequipa between March 13 and June 5, 1912. The following discussion of these has been made by Miss Cannon.

March 13. Seven photographs were taken, the middle of the times of exposure expressed in decimals of the day following Greenwich Mean Noon, being 0.644, 0.671, 0.687, 0.702, 0.721, 0.743, and 0.754, respectively. The spectrum at this time was totally unlike that of any other Nova so far observed, and resembled that of the Sun, except that the hydrogen lines were stronger. It appeared, therefore, to belong to Class F5, having also several of the dark lines unusually well marked. This is only the second instance in which the spectrum of a new star has been photographed while it was still increasing in light. The other case was the bright new star of 1901, Nova Persei, No. 2, whose spectrum at first resembled that of Class B8. See H.C. 56. In both of these cases, the spectrum characteristic of new stars did not appear until the maximum light was reached. Spectra of Nova Geminorum on several dates are shown in Figure 3. They were taken on isochromatic plates and are here enlarged ten times. These prints are negatives, so that bright lines appear dark. The first spectrum of Figure 3 is that of α Canis Minoris, which is given here for purposes of comparison. It was taken with the same dispersion and under the same conditions as the spectra of the Nova. The second spectrum of Figure 3 was taken on March 13.702, exposure 21^m. A dark line or band at the approximate wave length 4739 is present in the spectrum of the Nova, but not in that of α Canis Minoris. Lines near the wave length 4175 are also stronger in the Nova, and there are probably other differences in individual lines, not affecting, however, the general type of the spectrum. On this, and other nights, no change was noticed in the spectrum during the evening.

March 14. Seven photographs were taken, the decimals of the day being 0.513, 0.534, 0.567, 0.594, 0.629, 0.658, and 0.681, respectively. The third spectrum of Figure 3 was taken on March 14.658, exposure 31^m. A change had taken place, and the type is transitional between the spectrum of March 13, resembling the Sun, and the characteristic Nova type. In some respects, its general appearance resembles that of March 13, but the dark lines Hβ, Hγ, Hδ, Hε, and K now have broad, bright bands on the edge of greater wave length. On the ordinary plates, the bright band accompanying Hβ is seen to be slightly more intense than the other bands, although it nearly disappears in Figure 3, owing to the absorption of the isochromatic plate. Other bright bands or spaces appear, three being clearly seen between Hγ and Hδ. A trace of the bright lines, 4922 and 5016, is seen.

March 15. Two photographs were taken, the decimals of the day being

0.596 and 0.719, respectively. The first of these plates was taken at Arequipa, the second, at Cambridge, where the weather conditions were poor. The Arequipa plate shows that the transition to the Nova type was almost complete. The intensity and width of the bright hydrogen lines, have increased and the narrow dark lines present on March 13, have disappeared or been changed into wide bands with bright spaces between them.

March 16. Five photographs were taken, the decimals of the day being 0.519, 0.591, 0.652, 0.678, and 0.751, respectively. The transition to the Nova type appears to be complete. The dark lines of hydrogen are barely visible while the bright bands are very intense and broad with faint lines of reversal superposed. The dark bands H and K are still present. The entire spectrum appears to be composed of bright and dark bands or spaces.

March 17. Two photographs were taken, the decimals of the day being 0.537 and 0.571, respectively. The fourth spectrum of Figure 3 was taken on March 17.571, exposure 60^m. The spectrum resembles that of March 16, except that the dark bands H and K have become fainter, and the maximum intensity of the bright lines, $H\beta$, $H\gamma$, and $H\delta$ has shifted towards the edge of greater wave length.

March 18. Four photographs were taken, the decimals of the day being 0.540, 0.582, 0.615, and 0.756, respectively. The continuous spectrum appears to be much fainter than on March 17. The dark bands, $H\delta$, $H\epsilon$, and K, are again well marked, and divided into two portions. The lines of reversal, superposed upon the bright $H\beta$, $H\gamma$, $H\delta$, $H\epsilon$ and K, are stronger than on previous dates.

March 19. One photograph was taken, the decimal of the day being 0.525. This plate is not very good, and no change in the spectrum is detected since March 18.

March 20. Four photographs were taken, the decimals of the day being 0.519, 0.580, 0.584, and 0.641, respectively. The only noticeable change in the spectrum is that the bright band K, which on March 17 was about equal to band H in intensity, is now decidedly fainter than H.

March 22. Three photographs were taken, the decimals of the day being 0.525, 0.568, and 0.731, respectively. The fifth spectrum of Figure 3 was taken on March 22.525, exposure 50^m. The dark hydrogen lines accompanying the bright bands are of well marked intensity, and are seen from $H\beta$ to $H\theta$, inclusive. The bright band K, which was observed to be faint on March 20, has now disappeared, and only a narrow dark line remains.

March 23. One photograph was taken, the decimal of the day being 0.528. This plate is poor. The spectrum appears to be like that of March 22.

March 25. Two photographs were taken, the decimals of the day being 0.567, and 0.743, respectively. These plates do not show much detail and no certain changes are observed.

March 26. One photograph was taken, the decimal of the day being 0.573. This plate is poor, and shows only the bright bands.

March 27. Three plates were taken, the decimals of the day being 0.517, 0.541, and 0.574, respectively. An increase in brightness of the portion of the spectrum at about the wave length 4640, has occurred since March 22. The continuous spectrum is faint and the dark hydrogen lines are not clearly seen.

March 29. Two photographs were taken, the decimals of the day being 0.615, and 0.649, respectively. The spectrum appears to be similar to that of March 27.

March 30. Five photographs were taken, the decimals of the day being 0.511, 0.526, 0.547, 0.580, and 0.659, respectively. The continuous spectrum appears to be much more intense than on March 26, 27, or 29. The dark hydrogen lines are again present on the edge of shorter wave length of the bright bands and are distinctly double. The dark band K, which is present and fainter than band H, is also double. The spectrum in general resembles that of March 22, but differs in the portion between $H\beta$ and $H\gamma$, owing chiefly to the increased intensity of the bright band 4640.

April 3. Two photographs were taken, the decimals of the day being 0.611, and 0.636, respectively. The dark hydrogen lines are fainter than on March 30. The dark band K, is now more intense than the band H.

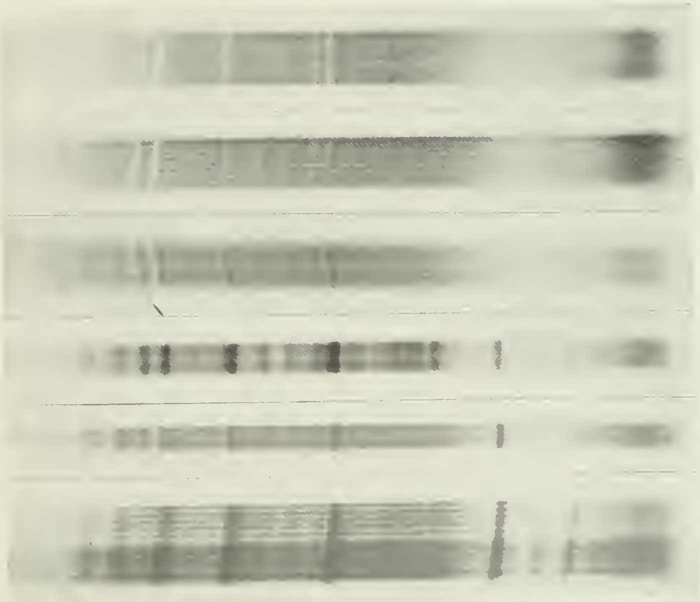
April 4. One photograph was taken, the decimal of the day being 0.636. The dark components of the hydrogen lines are not seen and the spectrum resembles that of March 27.

April 5. Two photographs were taken, the decimals of the day being 0.572 and 0.595, respectively. It has been stated that during March, there were striking variations in the dark hydrogen lines, and that they were sometimes absent and then appeared again with marked intensity. These changes were probably connected with the variations in the light. On the plates taken in April, there is a somewhat similar variation in a dark band situated on the edge of shorter wave length of the bright hydrogen band $H\delta$. This may be the dark band $H\delta$, and will be so designated for convenience of reference. This dark

Pls 76 4a

Fig. 1. March 10, 1912.

Fig. 2. March 11, 1912.



α Canis Minoris. April 20, 1912.

Nova Gemin., No. 2. March 13, 1912.

" " " March 14, 1912.

" " " March 17, 1912.

" " " March 22, 1912.

Nova Persei, No. 2. March 7, 1901.

Fig. 3. Spectra.

NOVA GEMINORUM, NO. 2.

Fig. 1. March 10, 1912.

Fig. 2. March 11, 1912.

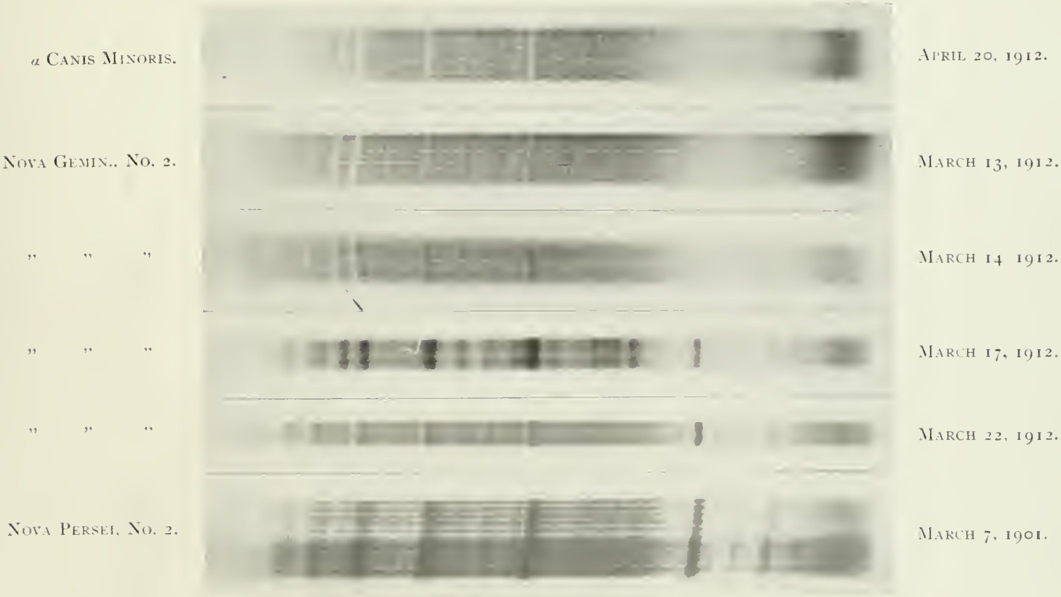


Fig. 3. Spectra.

NOVA GEMINORUM, NO. 2.

band is seen on the plates taken on April 5, and the intensity is estimated to be 5.

April 6. One photograph was taken, the decimal of the day being 0.538. The dark band Hδ is not seen and the spectrum is like that of April 4.

April 7. One photograph was taken, the decimal of the day being 0.519. The spectrum is like that of April 4.

April 8. Two photographs were taken, the decimals of the day being 0.528 and 0.624, respectively. The dark band, Hδ, is seen, but it is faint, intensity 1.

April 9. One photograph was taken at Arequipa, the decimal of the day being 0.541. The spectrum differs from that of April 8, only in the increased intensity of the dark band Hδ, which now has intensity 10.

April 10. One photograph was taken at Cambridge, the decimal of the day being 0.569. The spectrum is like that of April 8, and the dark band Hδ is faint, having intensity 1.

April 12. One photograph was taken at Arequipa, the decimal of the day being 0.516. The spectrum is like that of April 9. The continuous spectrum is fainter than on April 10, and the dark band Hδ is present, having intensity 10.

April 13. One photograph was taken at Arequipa, the decimal of the day being 0.513. The spectrum in general resembles that of April 8. The dark band Hδ, however, is wider than on April 8, and its intensity is estimated to be 5.

April 14. One photograph was taken, the decimal of the day being 0.545. The plate is not very good, and only the bright bands are seen.

April 16. One photograph was taken, the decimal of the day being 0.522. The spectrum is stronger than on April 14. The dark band Hδ is seen, and the spectrum appears to resemble that of April 9.

April 17. One photograph was taken, the decimal of the day being 0.506. The definition is poor, perhaps owing to the low altitude. No certain change is observed.

April 18. One photograph was taken, the decimal of the day being 0.523. The definition is poor, perhaps owing to the low altitude. No certain change is observed.

April 19. One photograph was taken, the decimal of the day being 0.499. The dark band Hδ is present, with intensity 10. The spectrum appears to be very nearly like that of April 9.

April 20. Two photographs were taken, the decimals of the day being 0.508, and 0.540, respectively. This spectrum resembles that of April 19, in the presence and intensity of the dark band Hδ. However, several of the dark bands appear narrower than on April 19, and a wide, dark band between Hδ and Hε has a shorter wave length than on April 19.

April 21. One photograph was taken, the decimal of the day being 0.506. The lines appear broader than on April 20, but this may be due to atmospheric conditions.

April 30. One photograph was taken, the decimal of the day being 0.547. No certain change is observed since April 21.

May 10. One photograph was taken, the decimal of the day being 0.582. The continuous spectrum has become very faint, and several changes have occurred since April 30. The most important are the increased intensities of bands 4640 and 5016. Band 4640 is narrower than on previous dates, but is now slightly more intense than Hβ. Band 5016, which on previous plates is slightly fainter than 4922, is now a strong band, while band 4922 is barely seen. This increased intensity of 5016 may be due to the presence or increased brightness of the nebular line, 5008, which would be superposed on the helium line 5016, with this dispersion. A bright band has also appeared near Hγ, towards the edge of greater wave length.

June 3. One photograph was taken, the decimal of the day being 0.580. The plate is poor and shows no certain change since May 10.

June 5. One photograph was taken, the decimal of the day being, 0.577. The plate is poor and shows no certain change since May 10.

The last spectrum of Figure 3 is that of Nova Persei, No. 2, on March 7, 1901, which is given here for purposes of comparison with the spectra of Nova Geminorum, No. 2.

THE VARIABLE STAR, 87.1911.

ANNOUNCEMENT was made by Mr. C. R. D'Esterre in the Astron. Nach. 190, 163, of a "Nova or new variable star" whose position for 1900 is R. A. = $2^h\ 3^m\ 16^s.3$, Dec. = $+56°\ 42'.8$. The designation 87.1911 has been assigned to this object. The star was conspicuous on plates taken by D'Esterre on November 13 and 21, 1911, but was not seen on plates taken on three previous dates. Professor Wolf, Astron. Nach. 192, 7, on a plate taken

April 3, 1912, found two stars near this position, of which the northern was slightly the brighter. On October 10, 1904, the northern component was not seen and was certainly fainter than the sixteenth magnitude. An examination of the Harvard photographs by Miss Cannon showed that the star was of about the eleventh magnitude on three dates, October 30, 1896, September 17, 1899, and January 28, 1902. On sixty-seven other plates taken with the 8-inch Draper Telescope no trace of the object is visible, although stars as faint as the fourteenth magnitude are shown. A plate taken with the 8-inch Bache Telescope on November 3, 1885, with an exposure of 60 minutes, although showing faint stars, does not show this variable.

While these observations show that this object is certainly not a Nova, it appears to be a variable of large range, which is bright during a relatively short portion of the time. The period does not appear to be uniform, and the object perhaps belongs to the class of U Geminorum and SS Cygni.

EDWARD C. PICKERING.

JULY 29, 1912.

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MAY 2
UNIVERSITY

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 177.

MAXIMUM BRIGHTNESS OF ALGOL VARIABLES.

THE first step in determining the changes in light of a variable star of the Algol class, is to measure the maximum brightness on a uniform scale which shall be the same for all parts of the sky. The published maxima are frequently those given by the discoverer, and the scales used by different astronomers, especially for the fainter stars, often differ by a large amount. Sequences of comparison stars for all Algol and short period variables, north of declination −30°, which have a maximum magnitude of 11.0, or brighter, and a range of one magnitude, or more, have been prepared at this Observatory. These magnitudes have been determined on the scale of the meridian photometer, as in the case of the variables of long period in H.A. 57, Part 2. This work, which will form H.A. 63, Part 2, is now ready for the printer, and will probably be issued in the autumn.

TABLE I.

MAXIMUM MAGNITUDES.

Designation.	Name.	No.	Magn.	A. D.	Diff.
023341	Z Persei	16	9.91	.08	+0.1
025338	ST Persei	12	9.70	.04	−0.3
035727	RW Tauri	12	8.38	.06	−0.5
041342	RW Persei	15	9.60	.08	−0.8
044880	RS Cephei	7	10.25	.11	−0.7
054231	RZ Aurigae	10	11.60	.04	−0.1
072776	Y Camelopardalis	4	10.11	.09	−0.4
094233	T Leonis Minoris	5	9.46	.05	. .
113972	Z Draconis	12	10.11	.04	+0.3

Mr. Frank E. Seagrave has kindly volunteered to undertake an extensive series of observations with the 15-inch East Equatorial of this Observatory.

Observations have already been obtained of a number of Algol variables. The method of observation is extremely simple, and is that now employed in many of the observations of variables made here, both photographically and visually. The magnitude is estimated directly from the magnitude of the next brighter and next fainter star of the sequence. The magnitudes are ordinarily taken to tenths, but occasionally the estimates are made to twentieths. Some of the results already obtained are given in Table I. The designation, the name, the number of nights of observation, the mean magnitude, and the average deviation of the mean, are given in the successive columns.

The best previous determinations of these magnitudes are those given by Hartwig in the V. J. S. 47, 186. The differences, found by subtracting from these values those in the fourth column, are given in the last column of Table I. All but two give negative values, perhaps due to the tendency of a discoverer to overestimate the brightness of a new object.

EDWARD C. PICKERING.

March 20, 1913.

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EDWARD C. PICKERING.

MARCH 20, 1913.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 178.

STARS HAVING PECULIAR SPECTRA.

In the course of the observations for the Revised Draper Catalogue, Miss Cannon has so far added ten stars to the list of those known to have bright lines in their spectra, and has found twenty-four new composite spectra. Table I contains a list of the first of these, and Table II, of the second. In Table I, the successive columns give the number in the Durchmusterung, the right ascension for 1900, the declination for 1900, the photometric or Durchmusterung magnitude, the class of spectrum, and a brief description of the observed peculiarities.

TABLE I.

SPECTRA HAVING BRIGHT LINES.

DM.	R. A. 1900.		Dec. 1900.		Magn.	Sp.	Description.
	h.	m.	°	′			
+37° 1160	5	15.8	+37	35	7.39	B0	Hβ bright. Absorption lines faint.
+35° 1095	5	19.0	+35	33	8.3	B	Hβ bright. Spectrum nearly continuous.
+25° 941	5	37.5	+25	24	6.86	B	Hβ bright. Lines indistinct.
+ 5° 1448	6	46.5	+ 5	13	6.76	B2	Hβ bright.
−11° 1760	6	59.0	−11	24	9.0	B0	Hβ and Hγ bright.
−25° 4439	7	18.6	−25	49	6.98	B1	Hβ bright.
−36° 3715	7	30.2	−36	7	5.51	B0	Hβ bright.
− 2° 2379	7	55.8	− 2	36	6.43	B3	Hβ bright.
−58° 6964	16	53.2	−58	48	6.32	B2	Hβ bright.
+35° 3930	19	59.8	+35	45	6.69	Oe	Bands 4633 and 4688 bright.

REMARKS.

+37° 1160. Attention was called to this spectrum by Professor Schwarzschild, who found Hγ and Hδ to be missing. It was accordingly photographed with the 11-inch Draper Telescope on October 26, 1911. Hβ was found to be bright, Hγ and Hδ to be very faint and dark, showing only slight contrast to the continuous spectrum. The bright line Hβ was later found independently in classifying spectra for the Revised Draper Catalogue.

Lists of stars having composite spectra are published in H.A. 28, 93, 229, and H.A. 56, 113, 160. About one half of these stars are known to be double, either visually or spectroscopically, and it therefore seems reasonable to suppose that other stars having spectra with similar peculiarities, are also double.

Table II gives a list of stars having composite spectra, in addition to those already known. The first four columns contain the Durchmusterung number, the right ascension for 1900, the declination for 1900, and the photometric or Durchmusterung magnitude, the latter being carried to tenths only. The fifth column gives the number in Burnham's "General Catalogue of Double Stars," for stars contained in that work. The sixth and seventh columns give the class of spectrum of the brighter and fainter components, as nearly as they can be determined from the blended spectrum. It should be

TABLE II.

STARS HAVING COMPOSITE SPECTRA. 19 NEW DOUBLE STARS.

DM.	R. A. 1900.		Dec. 1900.		Magn.	Burnham.	Br.	Ft.
	h.	m.	°	′				
+43° 628	2	59.2	+43	19	7.30	1555	F5	A3
−54° 599	3	45.9	−54	36	7.00	..	F5	A2
+20° 744	4	16.5	+20	35	6.11	2149	K0	A
−11° 1117	5	11.5	−11	28	6.51	..	G0	A2
+46° 998	5	13.1	+46	52	6.48	2637	A2	G
+20° 1100	5	41.7	+20	54	8.0	2961	F0	A
+ 1° 1148	5	45.3	+ 2	0	6.26	..	G0	A
−52° 791	5	48.2	−52	48	6.34	..	F5	A
+35° 1345	6	1.8	+35	8	7.67	..	F0	A
+14° 1286	6	20.1	+14	9	7.7	..	F0	A
−23° 4144	6	34.2	−23	29	6.61	..	F5	A3
+16° 1273	6	41.0	+16	52	6.68	..	F5	A5
− 5° 1864	6	49.3	− 5	53	8.0	..	K0	A2
− 7° 1642	6	52.2	− 8	3	6.44	..	F5	A2
+37° 1645	6	57.6	+37	44	6.63	..	F5	A
−20° 1951	7	23.2	−20	57	7.8	..	G0	A
+23° 1812	7	42.6	+23	24	6.21	..	F2	A
+54° 1195	7	56.8	+53	57	7.05	..	F2	A2
+21° 2156	10	3.8	+20	49	6.65	..	F5	A
+16° 2642	14	19.4	+16	44	6.77	..	K0	A
−16° 4836	18	16.0	−16	22	7.8	..	K0	A
+47° 2743	18	59.4	+47	9	7.8	..	A0	G
+29° 3651	19	30.9	+29	14	5.42	..	F5	A
+18° 4252	19	44.3	+18	37	7.05	..	G0	A

noted that the brighter component appears to belong to a later class of spectrum in all cases except two. The star +23° 1812, R.A. $7^h\ 42^m.6$, Dec. +23° 24′, is a known double star, but the observed visual companion, magn. 13.5, is too faint to cause the composite spectrum. The brighter star is probably double.

A photograph of the spectrum of Nova Geminorum, No. 2, taken on April 5, 1913, shows only slight changes since November 9, 1912, when the brightest band was at wave length 4363. The portion of the spectrum from 4686 to 5007 resembles that of the prevailing type of gaseous nebulae such as N. G. C. 7662, but differences occur in other portions of the spectrum. Lines Hδ, 4363 and 4640 are more intense in the Nova, while line 3869 is more intense in nebulae. The spectrum of the variable star, RU Camelopardalis, 071069, is peculiar, and probably belongs to Class R. This star is a variable of short period, and is the only one, so far known, to have a spectrum of this class.

EDWARD C. PICKERING.

APRIL 21, 1913.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 179.

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25 NEW VARIABLE STARS, PRINCIPALLY IN HARVARD MAPS 39 AND 45.

THE following description of new variable stars, found usually while examining photographs taken with the 1-inch Cooke Anastigmat, has been prepared by Miss Leavitt.

The plates superposed comprised 5 for Harvard Map 39, centre at R.A. = 10^h, Dec. = $-30°$, and 6 for Map 45, centre at R.A. = 22^h, Dec. = $-30°$. One more than the customary number was employed for Map 45, because the examination of the earlier plates was less thorough than usual. The principal results are given in Table I, in the same form as Table I in H.C. 130.

TABLE I.

NUMBER AND DISTRIBUTION OF THE VARIABLES.

No.	Region.	New Variables.	Total Found.	Proportion New.	All.	Probable Number.	Proportion Found.	Probable No. Unknown.	Proportion Unknown.
	h °								
39	10, −30	14	22	.64	34	55	.40	21	.38
45	22, −30	9	21	.41	37	49	.43	12	.24

The known variables found were *084047*, *084146*, T Antliae, X Hydrae, Y Hydrae, SU Velorum, X Velorum, and U Antliae, in Map 39, and RS Capricorni, *210445*, RX Aquarii, S Microscopii, R Gruis, S Piscis Austrini, R Piscis Austrini, X Aquarii, RT Aquarii, T Gruis, S Gruis, and Y Sculptoris, in Map 45. The variable *210445*, discovered by Miss Leland, as announced in H.C. 152, and re-discovered during this examination, was found to be of special interest, as the period is short, probably about nine-tenths of a day, and the maximum very brief. The range, 1.5 magn., is large for a variable having so short a period.

The new variables are given in Table II. The successive columns contain the designation, Harvard number, constellation, Durchmusterung number, right ascension for 1900, declination for 1900, brightest and faintest magnitudes observed on a provisional scale, and observed range. The number in the fourth column is usually taken from the Cordoba Durchmusterung, but it is taken from the Cape Photographic Durchmusterung for Variable *114760*, and from the Bonn Durchmusterung for variables north of the declination −23°.

TABLE II.

NEW VARIABLE STARS.

Design.	H. V.	Constellation.	DM.		R. A. 1900.			Dec. 1900.		Bright.	Faint.	Range.
					h.	m.	s.	°	′			
012629	3347	Triangulum	. .		1	26	9	+29	51.5	10.5	11.8	1.3
090031	3348	Pyxis	. .		9	0	32	−31	58.7	7.4	14.1	6.7
090843	3349	Vela	−43°	5040	9	8	44	−43	22.1	8.5	9.5	1.0
092234	3350	Pyxis	−34°	5884	9	22	54	−34	28.1	9.8	10.6	0.8
092934	3351	Antlia	−34°	5985	9	29	30	−34	16.4	10.0	10.6	0.6
093320	3352	Hydra	. .		9	33	14	−20	12.1	9.4	<12.0	>2.6
094644	3353	Vela	−44°	5914	9	46	12	−44	11.3	9.5	10.7	1.2
094629	3354	Antlia	−29°	7842	9	46	42	−29	25.6	9.2	10.2	1.0
094921	3355	Hydra	−21°	2931	9	49	4	−21	22.6	9.4	10.4	1.0
100229	3356	Antlia	. .		10	2	14	−29	35.1	9.3	<12.0	>2.7
100434	3357	Antlia	−34°	6457	10	4	9	−34	41.3	9.1	9.9	0.8
101129	3358	Antlia	−29°	8222	10	11	31	−29	13.3	9.2	10.0	0.8
101645	3359	Vela	−45°	5971	10	16	9	−45	44.0	10.2	<12.0	>1.8
101634	3360	Antlia	. .		10	16	41	−34	17.7	7.7	<12.0	>4.3
104134	3361	Antlia	−34°	6961	10	41	22	−34	43.9	9.6	10.6	1.0
114760	3362	Centaurus	−60°	3454	11	47	32	−60	58.1	8.3	8.7	0.4
210034	3363	Microscopium	−34°	14866	21	0	54	−34	40.3	9.6	10.6	1.0
211030	3364	Microscopium	−30°	18489	21	10	21	−30	42.1	11.0	11.8	0.8
214542	3365	Grus	−42°	15664	21	45	39	−42	50.5	9.5	10.0	0.5
215722	3366	Aquarius	−22°	5820	21	57	20	−22	0.1	10.1	10.6	0.5
220233	3367	Piscis Austrinus	−33°	15917	22	2	8	−33	19.9	10.0	<11.5	>1.5
220623	3368	Aquarius	−23°	17297	22	5	59	−23	16.3	10.7	11.3	0.6
223017	3369	Aquarius	−18°	6151	22	30	5	−17	46.5	9.0	9.8	0.8
223544	3370	Grus	−44°	15009	22	35	26	−44	21.7	9.5	10.0	0.5
223721	3371	Aquarius	−21°	6288	22	37	26	−21	42.0	9.2	<11.0	>1.8

REMARKS.

012629. This star was one of a sequence measured on two plates for Kapteyn Region 45, and was discovered to be variable through the discordance of the resulting magnitudes. It is of the Algol type, having been found faint on only 17 out of nearly 300 plates examined.

090031. This star was bright during the spring of 1902, and for some time after its discovery was supposed to be a Nova. After it had been looked for on more than 400 photographs, however, it was again found very bright on a photograph taken with the 8-inch Bache Telescope on May 28, 1890. A star of about the fourteenth magnitude appears in the same position on all photographs, about 30 in number, which show objects of that degree of faintness. Its light appears to vary slightly with a range of not more than two or three tenths of a magnitude. The dates and estimated magnitudes on plates nearest the time of the appearance in 1890, and on all plates taken between March 19 and July 3, 1902, are as follows: — May 2, 1890, 14.0; May 5, 1890, 14.0; May 28, 1890, 7.5; April 22, 1892, 14.2; March 19, 1902, not seen on a plate showing stars of the magnitude 10.5; April 2, 1902, 9.00; April 7, 8.00; April 29, 7.55; May 2, 7.45; May 27, 8.20; May 28, 8.00; May 29, 8.05; May 31, 8.00; June 9, 8.15; June 10, 8.30; June 19, 8.20; July 3, 9.10. No more photographs of this region were taken until September 26, when the star was not seen on a photograph showing stars of the magnitude 11.5. On October 9 it was not seen on a plate showing stars of the magnitude 12.5. It has not appeared brighter than the fourteenth magnitude on any of 268 plates taken since October 9, 1902. Unfortunately, its image has not been found on any spectrum plate. The form of the light curve is clearly that of a Nova. It may be necessary to revise the definition of such stars to cover the possibility of there being more than one appearance. Twelve years elapsed between the two observed appearances, and if the outbursts are periodic it should be seen again in 1914.

100434. This variable is of the Algol type. Observations of 7 minima between January 3, 1903 and May 26, 1909 give the approximate formula, J.D. 2,410,002.96 $+3^d.0519$ E.

101129. Period short, and maximum evidently very brief.

101645. This variable is of the Algol type. Eighteen minima are satisfied by the formula J.D. 2,410,001.57 $+2^d.10838$ E.

114760. This variable was discovered during the examination of Harvard Map 50, but was not announced in Circular 122 on account of its small range. It is of the type of β Lyrae, and the times of minima are well represented by the formula, J.D. 2,410,001.7 $+2^d.4645$ E.

210030. This variable is perhaps of the Algol or β Lyrae type. The brightness appears to be nearly constant on 20 out of 24 plates examined.

214542. This variable is of the Algol or β Lyrae type. The period is one of the shortest known, and is closely represented by the formula, J.D. 2,410,000.13 $+0^d.20547$. The object is fainter than the normal brightness during more than one-third of the entire period.

215722. The variability of this star is well established, notwithstanding its small range, as good comparison stars are near.

220233. This variable is of the Algol type. The times of minima are approximately represented by the formula J.D. 2,410,001.8 $+8^d.18$ E.

223544. This variable is of the Algol type. The times of minima are approximately represented by the formula J.D. 2,410,001.60 $+1^d.47603$ E.

The variable *090843* was originally discovered in July, 1908 by Mrs. Fleming, who recorded its spectrum as "Mc 5d var ?" on Plate B 38415, taken February 5, 1908. Announcement was withheld on account of the small range. It was again found by Miss Cannon in January, 1910, while comparing chart plates in Harvard Map 49. The photographs on which it was found by Miss Leavitt show the variable near the edge. This independent discovery of the same variable by three people, notwithstanding its small range, is of interest as an illustration of the thoroughness with which the heavens may be studied on plates belonging to the Harvard collection. Of the new variables, those designated *090843*, *092234*, *093320*, *094644*, *100229*, *101634*, *104134*, *210034*, and *223721*, probably have long periods, while the periods are probably short for *094629*, *094921*, *101129*, *220623*, and *223017*, as well as for the Algol variables mentioned below. The variable *090031* seems to have all the characteristics of a Nova, excepting that two appearances have been observed, the first in 1890, the second in 1902. Further information concerning it is given in the Remarks. The variables 012629, *100434*, *101645*, *114760*, *214542*, *220233*, and *223544* are of the Algol or β Lyrae type, and the periods of all but the first-mentioned are given in the Remarks which follow the Table. Of these, *114760* has been observed on a large number of plates, and a full ledger prepared. The others will be more fully observed later, and the periods are subject to correction.

EDWARD C. PICKERING.

May 12, 1913.

DEC 31 1913
UNIVERSITY OF TORONTO

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 180.

SPECTRA OF 825 STARS NEAR THE NORTH POLE.

In the preparation of the Revised Draper Catalogue, Miss Cannon has now classified the spectra of a hundred and ten thousand stars, covering more than half of the sky. Numerous requests are received from astronomers for the spectra of especial objects, and these are furnished so far as it can be done. Applications have been received from three different countries, for the spectra of stars near the North Pole. Miss Cannon has accordingly prepared the following list of the spectra she has classified of stars within ten degrees of the North Pole. All stars are included having a magnitude in the Durchmusterung of 8.3, or brighter. The three columns of Table I give the number in the Durchmusterung, the photometric or Durchmusterung magnitude, the latter being given to tenths only, and the class of spectrum. The scale of the Durchmusterung for stars in this part of the sky agrees almost exactly with the photometric scale, except for stars fainter than the magnitude 9.2.

TABLE I.

SPECTRA OF STARS NEAR THE NORTH POLE.

DM.	Magn.	Sp.	DM.	Magn.	Sp.	DM.	Magn.	Sp.	DM.	Magn.	Sp.	DM.	Magn.	Sp.	DM.	Magn.	Sp.
+89°			+88°			+88°			+87°			+87°			+87°		
3	8.85	A5	9	8.01	F0	90	8.97	K0	1	9.0	A	78	8.27	F5	121	8.9	G5
13	7.01	A0	11	8.40	G0	104	8.11	F5	9	8.8	F5	79	8.5	K0	122	8.8	F2
21	9.00	F	13	8.61	A	105	8.20	K0	12	8.04	K0	80	8.5	K0	143	7.16	K0
22	8.67	K0	39	8.91	F0	110	8.76	F5	15	7.84	A3	83	7.97	G5	147	8.07	F8
			60	8.74	F8	112	6.55	Mb	16	8.64	G0	85	8.5	K0	151	8.9	F8
+88°			64	7.44	B8	114	8.26	K0	23	8.43	K0	99	8.8	G5	169	8.1	F0
			71	6.28	F0	115	8.88	A2	33	8.42	F2	101	7.76	A2	180	8.30	A5
			76	7.57	K2	117	8.35	G5	41	8.64	K0	104	8.2	K5	181	8.34	A3
2	8.10	K0	77	8.45	F2	130	9.11	F	46	8.5	G5	107	6.33	F2	187	8.04	K2
4	6.48	A2	80	8.92	A0	131	8.60	A5	51	5.26	Ma	115	8.4	F8	201	8.2	F8
8	2.12	F8	86	8.78	B9				68	8.8	G0	118	8.6	K0	205	7.37	A2

DM.	Magn.	Sp.
+87°		
217	8.5	A0
220	8.8	G5
+86°		
9	8.6	A3
14	8.8	G5
17	6.40	K0
21	8.8	G0
25	8.8	F5
38	9.0	A5
39	8.6	F0
51	5.84	F5
54	8.9	F0
65	8.3	G5
66	7.96	B9
67	8.7	G
79	6.57	G5
86	8.9	F8
91	9.0	A
96	8.5	G5
102	9.1	A0
103	8.2	G0
110	8.7	Ma
113	7.34	G5
126	8.24	K0
143	8.6	A3
146	8.9	A0
154	8.2	G0
159	8.3	A3
161	7.17	A2
170	7.37	F0
172	8.2	K0
176	6.38	F5
177	8.5	G
180	8.4	A0
182	7.07	F0
187	7.75	F8
193	8.04	F2
199	8.5	F5
201	7.44	F0
217	7.02	K0
221	8.1	F8
244	8.7	A0
256	8.5	G5
264	8.04	F2
+86°		
269	4.44	A0
272	5.86	A3
275	8.2	K0
282	6.82	Ma
318	8.34	F2
319	7.36	A3
324	8.2	A2
325	8.3	K0
326	8.3	K5
332	9.0	F2
335	8.07	A0
344	5.62	F0
347	8.6	F0
+85°		
2	8.9	G0
3	8.8	K0
9	8.3	K0
11	8.8	A2
19	4.52	K0
41	7.24	G5
45	8.73	A0
50	8.8	A0
63	6.70	F8
65	8.5	F5
74	6.54	A5
75	8.5	G5
78	6.55	A0
80	6.41	K0
81	7.61	G5
98	8.6	Ma
101	8.9	F0
105	8.2	F8
128	7.41	F2
129	8.2	G5
132	8.2	F0
142	8.5	G0
147	8.5	K5
150	7.94	G5
151	8.38	F8
155	8.56	G5
160	8.5	G0
161	7.44	K0
166	8.4	K0
170	8.68	G5
+85°		
183	7.35	K0
191	8.4	F5
196	8.2	A3
214	9.18	G5
222	7.35	G0
233	8.5	G
234	7.95	Ko
235	8.8	K
242	8.58	K0
249	7.41	K0
263	6.98	K0
264	8.93	K
266	8.8	G
269	7.05	A5
278	8.7	F8
294	7.50	F0
329	8.4	K0
330	8.9	G5
337	8.5	A5
340	7.95	K2
347	8.55	G5
354	7.91	K0
355	9.1	G5
357	8.98	F8
359	8.1	F0
367	8.5	A
376	8.5	F0
383	5.38	A0
384	6.78	K0
390	8.7	G5
398	8.5	K2
399	6.61	F0
400	7.76	G5
401	7.25	F5
403	7.18	A5
406	8.68	A0
409	6.71	A0
412	9.0	F0
+84°		
3	7.91	A2
4	9.2	A
9	9.0	G0
10	8.5	K0
13	9.0	A2
+84°		
14	8.33	K0
15	8.2	A5
18	8.8	F5
29	8.01	A5
30	9.0	A5
32	8.9	G5
34	8.1	G5
42	8.5	G5
48	9.2	A
59	5.78	K0
69	8.8	A2
78	7.41	K2
88	7.53	A2
90	9.1	A2
93	8.48	K0
97	8.8	F5
106	8.9	K2
112	8.78	G
114	8.9	F5
117	9.0	F5
118	8.8	F8
135	8.2	G5
152	7.81	K0
163	9.0	G5
168	7.38	A0
169	6.39	A0
173	8.8	F0
179	8.58	G0
186	7.41	F8
187	9.2	A3
196	6.26	F0
199	8.6	B9
206	8.05	G5
212	8.5	F0
213	8.3	K0
215	8.88	G
216	8.7	F2
217	8.7	K0
218	8.3	G5
222	8.20	G0
225	6.48	K0
234	5.64	A3
252	8.4	Ma
269	8.11	G0
274	8.11	K0
275	8.5	K
276	8.28	F8
+84°		
286	7.25	G0
289	5.81	A0
290	5.28	A2
296	8.6	K0
301	8.8	K2
302	8.7	F5
303	9.18	A
305	8.5	G5
307	7.65	F2
311	7.26	G5
322	8.52	K
335	7.12	K0
339	8.4	K0
345	8.3	F0
348	8.78	K0
351	7.06	A3
352	8.03	F8
354	9.3	F8
359	8.7	F2
360	8.33	A5
361	7.06	A2
370	9.0	K2
371	8.23	K5
378	7.73	A0
383	7.18	G5
387	8.6	K0
389	8.7	A3
391	8.9	G5
405	8.4	G5
406	8.2	A0
410	8.5	F0
412	7.38	F2
413	8.5	A5
423	8.6	F0
426	9.2	F8
436	9.2	F5
437	9.0	K2
445	8.5	A0
446	8.5	G0
448	8.8	A0
451	6.61	A2
461	8.5	K0
462	7.16	F0
463	7.11	F8
474	8.4	A2
505	8.05	G0
509	7.21	K0
+84°		
513	7.09	K0
516	7.60	Mb
517	6.18	K5
523	8.38	F
533	8.7	A2
536	8.2	K0
539	8.1	G5
546	8.2	A3
+83°		
1	8.5	F
9	7.12	F8
10	9.0	F8
11	9.2	F5
20	6.72	F5
30	9.3	A0
52	9.1	A2
54	8.9	A0
56	6.82	K0
58	9.0	A
60	9.0	K
79	8.2	G
91	7.52	B9
104	5.39	B3
114	7.36	K0
121	8.5	F5
126	8.5	K2
137	8.7	F5
139	9.0	G0
141	7.26	A0
142	9.0	K5
144	9.2	K0
145	9.3	A
149	8.7	K0
164	8.9	F0
172	8.5	G5
177	9.0	K0
178	8.9	K0
182	8.2	B9
191	7.99	K0
195	9.0	F
207	8.2	F8
220	8.5	K0
232	7.49	K0
233	7.06	F0

DM.	Magn.	Sp.
+83°		
236	8.5	G0
238	9.0	F0
240	9.0	G
243	8.3	F8
245	8.6	A5
248	8.4	F5
256	7.12	F5
262	7.49	A0
263	7.89	F0
280	7.59	K0
287	6.92	K0
297	5.34	F5
312	8.5	F8
318	8.2	F8
336	7.82	G5
339	8.32	A2
352	8.4	G
354	8.6	A5
365	8.6	A3
366	8.5	G5
369	7.19	K0
373	8.3	A0
381	9.2	K
397	6.16	G5
423	8.5	G5
431	5.73	G0
437	8.8	K5
439	9.0	K0
440	8.5	K2
441	8.8	K0
447	8.8	K2
452	8.4	G5
453	7.32	A2
456	8.5	F5
457	8.5	F5
464	9.0	G
468	8.2	G5
493	9.0	K0
501	8.8	K2
505	8.7	G5
511	8.3	A2
512	7.46	F8
524	8.8	G0
527	7.59	G5
530	7.82	G5
531	8.2	K2
533	8.8	A5
+83°		
534	8.5	F0
535	7.32	G5
536	6.15	A2
541	8.8	G0
547	6.81	A2
552	6.34	A2
556	8.7	F0
588	6.16	A2
594	8.8	K0
596	7.22	F2
603	7.06	G5
608	9.0	F5
613	8.6	F0
614	8.4	F5
616	8.8	A3
617	8.9	K0
618	7.02	A5
620	9.0	K0
622	9.0	A5
630	7.49	A0
640	4.96	K0
647	7.76	B9
+82°		
14	8.3	A2
20	5.55	A2
23	8.4	F8
30	9.0	A2
51	6.86	K0
55	8.7	F5
59	9.0	F8
60	9.2	G
76	7.21	G5
82	7.46	K0
90	8.2	A2
101	8.4	F0
105	9.0	F5
113	5.70	G5
125	8.5	B9
132	8.6	K0
133	9.0	F2
152	7.46	F8
155	8.7	K0
168	8.5	G0
174	9.0	G
+82°		
176	8.8	K0
177	6.39	A2
185	8.7	K2
188	8.7	K2
189	9.2	A2
191	9.0	K2
194	7.46	K5
201	5.11	Ma
204	8.5	F5
207	8.9	F5
213	7.60	B9
222	9.1	A
224	8.7	K2
228	9.2	F5
231	8.3	F5
235	6.17	A0
245	8.7	G5
251	8.7	F5
253	6.69	A0
259	9.1	K0
265	8.8	F0
268	8.5	F2
279	8.8	G
280	8.5	K0
300	8.1	K0
301	8.6	F8
305	8.9	F8
307	8.2	A5
308	7.66	K0
313	8.9	A3
320	8.8	A5
322	8.5	F8
325	7.06	G0
332	8.3	G0
342	8.16	G5
343	8.6	A3
348	8.3	F8
355	7.62	G5
356	6.28	K2
357	8.9	F5
365	8.16	F5
378	8.5	A3
388	8.5	K2
390	8.4	F5
395	8.5	A5
397	8.6	B8
407	8.2	A0
+82°		
423	9.0	A2
456	8.2	G0
463	6.92	F0
464	8.5	K0
470	8.2	F0
472	8.6	K2
475	8.6	G0
479	9.0	F5
481	8.5	A2
484	8.7	A5
485	7.82	A3
492	8.8	F5
497	8.3	F0
498	4.40	G0
505	8.3	F8
518	8.5	K0
521	8.5	A0
523	9.0	F5
537	8.3	K2
539	8.7	A0
540	7.29	B9
543	8.5	K0
546	8.19	K0
572	6.83	A0
578	7.99	B9
592	8.3	K0
598	7.93	K0
607	8.6	K0
608	8.5	A5
609	8.5	F8
611	9.1	A0
613	8.5	A0
617	6.82	G5
627	8.6	A5
636	8.5	A5
648	7.99	A2
650	8.6	G0
651	8.5	F8
657	8.5	G5
672	8.2	F0
673	7.12	F5
674	7.37	
682	8.5	K0
689	8.3	G5
700	7.46	B8
703	4.97	K0
704	7.56	K2
+82°		
707	8.5	K0
728	7.69	K0
735	8.2	G5
736	8.5	F0
743	6.42	A0
748	7.20	A0
+81°		
13	6.40	F8
18	7.54	G5
25	var.	A0
27	8.41	G
29	8.58	G
30	7.89	A0
51	8.7	A0
61	7.18	K5
88	9.1	F8
90	8.5	K2
95	8.6	F8
96	8.5	G5
107	7.26	Ma
125	8.10	G5
134	7.20	K0
135	7.63	F5
147	7.33	A0
149	8.3	A3
150	7.50	A0
162	9.2	A
168	8.5	F0
170	8.4	G5
174	9.4	A
177	9.2	F
178	8.7	G5
180	9.1	A0
183	8.6	G0
187	8.6	F2
192	8.5	A0
194	8.00	G5
201	8.8	G0
210	8.7	K0
214	9.0	G5
222	9.2	F2
225	8.4	K5
227	8.8	G0
228	9.1	G0
+81°		
231	8.9	G5
233	9.1	K2
239	8.38	K0
242	6.20	B9
243	9.0	F2
252	6.50	K0
257	7.13	K2
263	8.1	G5
268	8.9	G5
270	8.47	A5
272	9.3	A
273	7.73	F0
274	8.6	G5
278	7.83	F2
279	8.4	F8
282	6.53	F2
285	8.7	A3
286	9.2	K0
289	9.0	F8
295	8.6	K0
302	4.58	K0
308	8.9	A0
313	9.0	F0
319	8.07	G5
320	8.4	F8
322	9.5	F8
323	9.5	
337	7.67	G0
343	6.56	G5
347	8.4	F5
349	6.70	A0
350	9.0	G5
354	8.9	G5
359	8.2	G0
360	8.6	F5
362	8.2	G0
366	8.3	K0
369	9.0	A0
371	8.13	F8
373	6.13	A0
375	9.0	A0
379	9.0	G5
381	9.0	A2
384	8.5	A5
388	8.23	F8
389	6.44	Ma
399	8.1	G5

DM.	Magn.	Sp.	DM.	Magn.	Sp.	DM.	Magn.	Sp.	DM.	Magn.	Sp.	DM.	Magn.	Sp.	DM.	Magn.	Sp.
+81°			+81°			+80°			+80°			+80°			+80°		
400	7.37	F2	666	8.00	K5	36	6.73	A0	198	8.75	A3	377	9.3	F0	543	8.4	A2
402	6.26	A0	668	8.3	G	50	7.10	A0	202	7.42	F5	380	6.74	F0	544	5.91	K2
407	7.50	G5	687	8.00	F0	55	7.23	A0	204	8.1	G5	381	8.3		549	8.3	K0
412	7.30	G0	699	7.37	F5	57	7.50	A0	206	8.1	G5	383	8.5	K2	555	7.10	Ma
416	6.32	G5	706	8.10	F5	58	7.60	K0	207	8.3	K2	389	7.03	G0	575	8.0	G5
422	8.8	K0	710	8.5	K0	61	8.6	A	210	7.30	K0	390	9.00	A2	603	8.2	A3
427	9.2	A2	712	7.23	K0	64	5.99	A0	217	7.50	K0	393	8.3	G5	604	8.07	K0
435	8.9	K0	718	5.69	A0	65	6.77	A3	227	8.6	A0	394	9.2	F	606	8.33	K0
440	8.7	F5	725	8.13	F2	70	7.47	A0	230	7.30	K0	395	7.70	G5	607	7.53	K2
443	8.5	K2	729	8.7	F8	80	8.4	K5	233	8.47	F8	398	8.3	F5	609	7.50	A2
447	8.9	K0	735	7.73	K0	86	5.92	K0	237	8.7	K0	403	8.8	F5	614	8.1	G5
452	6.80	K0	736	7.47	K0	89	7.97	G5	238	6.47	G5	404	7.52	K0	631	8.43	A2
464	8.8	G5	737	7.83	F8	90	8.45	K0	240	6.92	K2	409	8.9	G5	644	8.3	K0
482	7.10	G5	742	8.07	G5	97	5.95	A2	241	8.25	G5	412	8.8	K	648	7.50	F0
483	8.7	F2	744	9.2	A0	103	8.6	A5	242	8.9	G5	417	7.53	K5	650	6.79	A0
495	7.20	A0	767	7.68	A0	121	7.87	K0	249	9.3	A5	421	7.20	K5	651	7.80	A5
504	8.9	G0	775	7.00	F2	123	8.3	A0	258	8.85	F2	422	7.40	G5	652	8.4	K0
510	7.30	G5	781	8.5	A0	125	5.25	F8	266	8.4	G0	432	8.3	A2	657	6.93	K0
517	6.97	K0	788	7.70	K0			A2	267	8.3	F0	447	8.9	G5	659	5.62	K0
523	6.97	G5	789	7.97	K	127	6.63	K0	268	8.3	F0	448	6.35	K0	660	6.10	K0
530	8.4	F8	795	8.9	A3	129	8.00	G5	272	7.47	A0	450	8.9	F5	672	5.58	K0
531	7.00	K2	801	7.63	K0	133	5.58	K0	276	8.90	G0	451	7.48	K0	679	6.93	F0
536	8.7	F	810	8.1	K2	134	7.17	A2	283	8.9	K0	452	8.5	K0	682	7.13	K2
538	8.35	A0	812	8.3	F2	138	8.7	G5	287	8.33	F8	459	7.70	A2	688	7.20	A0
541	7.60	K0	814	7.53	G0	140	7.27	F0	295	8.6	F5	464	8.95	G5	690	6.02	A2
542	8.5	F0	816	8.1	K0	143	8.8	G5	302	8.7	K0	465	8.37	K0	700	8.2	F5
543	8.2	G5	818	8.5	F8	146	7.87	G5	335	8.8	F8	466	8.1	K0	706	8.30	F2
549	8.2	G5	827	8.3	K	147	7.83	K0	338	7.87	K0	468	8.5	K0	731	6.90	F8
552	8.5	A0	832	8.8	K0	149	8.1	G5	339	8.5	G0	470	8.7	G0			A5
568	6.73	G5	838	8.57	A2	155	5.32	K0	344	8.6	G0	474	8.6	F8	739	8.17	A2
574	8.3	K0				156	9.1	A0	347	7.23	F8	478	8.40	A0	755	8.5	A2
619	7.67	A5	+80°			159	8.6	F0	350	8.13	K0	480	6.47	G5	770	8.2	A0
621	8.7	A5				168	8.4	K0	356	8.4	F0	481	8.3	G5	776	8.3	F2
622	7.50	K0				177	8.2	G5	358	8.3	Ma	487	6.93	F2	780	7.87	A0
643	8.2	K2	10	8.10	A0	181	7.90	A2	359	9.1	K0	489	7.83	F0	784	7.93	A5
655	8.3	A2	19	8.4	K0	183	8.8	K0	363	9.0	F8	511	7.80	G5	791	8.4	K0
659	8.03	F2	34	7.72	G5	190	9.02	A0	368	9.0	G5	519	6.95	G0	793	8.8	A
660	8.03	B9	35	7.20	F0	195	8.6	K	370	7.70	F8	530	7.93	G5			

EDWARD C. PICKERING.

December 2, 1913.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 181.

A CORRECTION TO THE PHYSICAL EPHEMERIS OF MARS.

THE following statement has been prepared by Professor W. H. Pickering from observations made by him at Mandeville, Jamaica: —

The longitudes of the central meridian of the disk of Mars, as published in the British Nautical Almanac, are continued from Marth's latest values, with an unaltered rate of rotation. It occurred to the writer that as a considerable number of years had now elapsed since these data were first employed, that it would be of interest to test their accuracy. He is not aware that this has been done recently. The point of Aryn from which all Martian longitudes are reckoned has not as yet developed upon the planet, but is due to appear in about two or three weeks. Edom promontory, which is located near it, developed some two months ago, and is now clearly defined. In looking over his drawings of the planet, made since that time, the writer has found eight, in which Edom is shown fairly near the centre of the disk. Table I gives the date of the drawing, the diameter of the planet, the distance of Edom from the central meridian as measured on the drawing, the resulting longitude, and the deviation from the mean. The results are doubtless less accordant than would have been the case had the drawings been made with this especial object in mind, but they show clearly a systematic deviation from the value given on Schiaparelli's chart, published in Flammarion's Mars, I, 440, where the longitude of Edom is given as 356°. Indeed only one of the drawings gives it a greater value.

It so happened this year that when Mars was in opposition, Edom was near the centre of the disk in the longitude of Jamaica. A few measures of it were therefore made with the micrometer. Two measures were secured upon each of three nights, each measure being the result of four readings, or twenty-four readings in all. Some improvements are planned in the micrometer, after which it is expected that Aryn itself will be visible, in which case more measures will be made.

TABLE I.

DRAWINGS OF MARS.

1913.	Diameter.	Distance.	Longitude.	Dev.	1914.	Diameter.	Distance.	Longitude.	Dev.
	″	°	°	°		″	°	°	°
October 30	10.3	+ 4	350	−2	January 4	15.0	−13	352	0
November 30	13.1	−10	350	−2	" 6	15.0	+ 4	355	+3
December 2	13.3	−15	349	−3	" 10	14.8	+16	358	+6
" 3	13.4	+ 3	349	−3	" 11	14.7	+ 4	351	−1
								352°	±2°.5

In Table II the successive columns give the date, the central meridian, the measured distance from the meridian reduced to degrees, the resulting longitude, the mean value for each date, the same corrected for phase, and the deviation. The result corroborates that obtained from the drawings as far as the sign of the correction is concerned, but reduces its value by a little over one-half. The early drawings seem to have been the defective ones. It indicates that a correction should be made to the ephemeris of the central meridian of +1°.78. Taking the mean of Schiaparelli's dates, and assuming that Edom was then correctly located in longitude 356°.0, it appears that the period of rotation of the planet is shorter than that heretofore adopted by $0^s.038$.

TABLE II.

MICROMETER MEASUREMENTS.

1914.	Central.	Distance.	Longitude.	Mean.	Phase.	Deviation.
	°	°	°	°	°	°
January 5	364.03	− 9.85	354.18			
" "	366.88	−12.59	354.29	354.24	354.24	+0.02
" 11	339.06	+16.31	355.37			
" "	342.03	+10.44	352.47	353.92	353.80	−0.42
" 12	358.38	− 1.78	356.60			
" "	361.08	− 8.12	352.96	354.78	354.62	+0.40
					354°.22	±0°.28

EDWARD C. PICKERING.

JANUARY 17, 1914.

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CIRCULAR 182.

THE VARIABLE STAR, *081041*, −41° 3911. H.V. 3372.

In H.C. 17, it is stated that the spectrum of the star C. DM. −41° 3911 had been found by Mrs. Fleming to be peculiar. A plate taken November 24, 1894 showed that the lines Hβ, Hγ, Hδ, and Hζ were bright, and the spectrum appeared to resemble that of η Carinae. Miss Cannon, in her regular classification of spectra, found this peculiar spectrum independently, from a much better plate taken January 8, 1897. Besides the lines mentioned above, the lines 4688, 4363, Hϵ, and 3869 were also bright. The spectrum, accordingly, resembled a gaseous nebula, or a nova when changing into a nebula. In identifying this object, Miss Mackie found that it was variable. The results of measures on 69 photographs are given in Table I. Owing to its position, this object is in opposition in the month of January of each year, and nearly all of the photographs were taken in the three or four months preceding and following. Those for each opposition are combined in a single group, the year of opposition, the number of plates, and the mean magnitude being given in the three columns of the table. Thus, the first group consisted of two plates taken on October 22, 1889, and April 1, 1890, with magnitudes 11.9 and 12.1, respectively.

TABLE I.

OBSERVED MAGNITUDES.

Yr.	No.	Magn.	Yr.	No.	Magn.	Yr.	No.	Magn.	Yr.	No.	Magn.
1890	2	12.00	1899	1	11.40	1904	1	14.10	1909	6	12.15
1894	3	11.13	1900	6	12.37	1905	1	14.10	1910	8	12.02
1896	2	11.60	1901	9	12.64	1906	2	13.25	1911	2	11.75
1897	1	11.70	1902	2	13.30	1907	4	13.25	1912	2	12.05
1898	3	11.30	1903	2	13.75	1908	12	12.46			

The nature of the variation is shown in Figure 1. It will be seen that the object is a very curious one. At first sight it might appear to be a variable star with a period of about twenty years, and varying from the eleventh to the fourteenth magnitude. Ordinary variables of long period have a very different spectrum and undergo all their changes in less than two years. The variations may prove to be irregular and to resemble those of the three stars of the class of R Coronae. Here again the spectrum is very different. The position of this star for 1900 is, R. A. $=8^h\ 10^m.8$, Dec. $=-41°\ 24'$. Evidently, additional observations of the light and spectrum of this star are much to be desired.

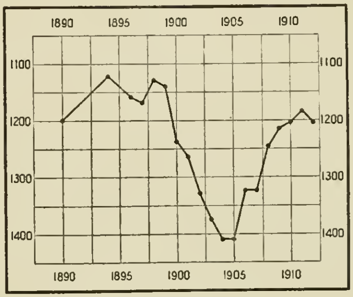

FIG. 1.

EDWARD C. PICKERING.

FEBRUARY 23, 1914.

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CIRCULAR 183.

OPPOSITION OF EROS (433) IN 1914.

THE opposition of Eros (433) on September 18, 1914, is not a particularly favorable one, as regards its distance from the Earth. The conditions are, however, excellent for a photometric study. It is far enough north to be followed, during the summer and autumn, for a large part of the night. The phase angle varies from 16° to 52°, so that the effect of phase can be studied to great advantage. An excellent ephemeris has been published in the Berliner Jahrbuch for 1916, p. (86). By the courtesy of Professor Cohn, Director of the Recheninstitut, the value of log r, of the phase angle, and of the computed magnitude have been furnished and are included in Table I. The successive columns give the Julian Day, the calendar day, the approximate right ascension for 1855, the approximate declination for 1855, the logarithm of the distance from the Sun, the logarithm of the distance from the Earth, the phase angle, and the computed magnitude. The latter is found by assuming the magnitude at distance unity from the Sun and Earth as equal to 10.60, and applying corrections for these two distances. No correction for phase angle has been made.

TABLE I.

OPPOSITION OF EROS IN 1914.

J. D.	Date.		R. A. 1855.		Dec. 1855.		log r	log Δ	Phase.	Magn.
			h.	m.	°	′			°	
0314	June	30	23	52.8	+ 5	16	0.240	0.111	35.6	12.35
0318	July	4	23	57.2	+ 6	19	0.238	0.096	35.6	12.27
0322	"	8	0	1.2	+ 7	23	0.237	0.080	35.5	12.18
0326	"	12	0	4.9	+ 8	28	0.236	0.064	35.3	12.10
0330	"	16	0	8.3	+ 9	33	0.234	0.048	34.8	12.01
0334	"	20	0	11.3	+10	38	0.232	0.031	34.4	11.92
0338	"	24	0	14.0	+11	44	0.230	0.014	33.9	11.82
0342	"	28	0	16.2	+12	50	0.228	9.997	33.1	11.93

J. D.	Date.		R. A. 1855.		Dec. 1855.		log r	log Δ	Phase.	Magn.
			h.	m.	°	′			°	
0346	August	1	0	17.8	+13	55	0.226	9.979	32.3	11.63
0350	"	5	0	18.8	+15	0	0.224	9.961	31.5	11.53
0354	"	9	0	19.2	+16	4	0.222	9.943	30.5	11.43
0358	"	13	0	18.9	+17	8	0.220	9.924	29.3	11.32
0362	"	17	0	17.9	+18	9	0.218	9.906	28.0	11.22
0366	"	21	0	16.1	+19	9	0.220	9.988	26.7	11.12
0370	"	25	0	13.5	+20	7	0.213	9.870	25.3	11.02
0374	"	29	0	10.1	+21	0	0.211	9.853	23.7	10.92
0378	September	2	0	5.9	+21	50	0.208	9.836	22.1	10.82
0382	"	6	0	0.7	+22	34	0.205	9.820	20.4	10.73
0386	"	10	23	54.8	+23	12	0.202	9.806	18.9	10.64
0390	"	14	23	48.1	+23	41	0.199	9.793	17.6	10.56
0394	"	18	23	40.8	+24	3	0.196	9.782	16.5	10.49
0398	"	22	23	33.1	+24	15	0.193	9.773	16.0	10.43
0402	"	26	23	25.4	+24	17	0.190	9.765	16.2	10.37
0406	"	30	23	17.6	+24	11	0.187	9.759	17.0	10.33
0410	October	4	23	10.0	+23	55	0.183	9.755	18.3	10.29
0414	"	8	23	3.0	+23	31	0.180	9.755	20.1	10.27
0418	"	12	22	56.7	+23	1	0.176	9.755	22.1	10.26
0422	"	16	22	51.3	+22	26	0.179	9.757	24.4	10.26
0426	"	20	22	46.8	+21	47	0.169	9.761	26.7	10.25
0430	"	24	22	43.4	+21	7	0.165	9.767	28.9	10.26
0434	"	28	22	41.1	+20	27	0.161	9.773	31.1	10.27
0438	November	1	22	39.9	+19	48	0.158	9.780	33.3	10.29
0442	"	5	22	39.8	+19	11	0.154	9.788	35.3	10.31
0446	"	9	22	40.7	+18	36	0.150	9.796	37.2	10.33
0450	"	13	22	42.5	+18	6	0.146	9.804	39.0	10.35
0454	"	17	22	45.4	+17	39	0.142	9.812	40.6	10.37
0458	"	21	22	49.0	+17	17	0.137	9.821	42.1	10.39
0462	"	25	22	53.5	+16	58	0.133	9.830	43.5	10.41
0466	"	29	22	58.8	+16	45	0.129	9.839	44.8	10.44
0470	December	3	23	4.7	+16	34	0.125	9.847	45.9	10.46
0474	"	7	23	11.1	+16	27	0.121	9.855	47.0	10.48
0478	"	11	23	18.3	+16	25	0.117	9.862	48.0	10.49
0482	"	15	23	26.2	+16	27	0.112	9.869	49.0	10.50
0486	"	19	23	34.7	+16	33	0.108	9.876	49.9	10.51
0490	"	23	23	43.7	+16	42	0.104	9.882	50.5	10.53
0494	"	27	23	53.1	+16	54	0.100	9.888	51.7	10.54
0498	"	31	0	3.1	+17	7	0.096	9.894	52.5	10.55

A reduction, now in progress, of the large series of observations made by the late Oliver C. Wendell has developed a new fact in the photometry of asteroids. It appears that Eros in 1898 was more than a magnitude fainter than in 1900.

Similar changes occur in other asteroids as was shown in the case of Juno (3) in H. A. 46, 201. After applying corrections for the distances of the Sun and Earth, for phase, and for variation due to rotation, there appears to be another large source of variation whose cause is difficult to explain. This furnishes an additional reason why observations not only of the relative, but also of the absolute, magnitude of Eros, are much to be desired this year.

EDWARD C. PICKERING.

MAY 10, 1914.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 184.

STARS HAVING PECULIAR SPECTRA.

CIRCULAR 178 gives a list of peculiar objects found by Miss Cannon in the course of her observations for the New Draper Catalogue. Table I contains an additional list of stars having spectra with bright lines or other peculiarities. The successive columns give the Durchmusterung number, the right ascension for 1900, the declination for 1900, the photometric magnitude or the Durchmusterung magnitude reduced to the photometric scale, the latter being carried to tenths only, the class of spectrum, and a brief description of the observed peculiarities. The letters H.V. refer to the catalogue of variable stars discovered at this Observatory.

TABLE I.

STARS HAVING PECULIAR SPECTRA. 6 NEW VARIABLE STARS.

DM.	R. A. 1900.		Dec. 1900.		Magn.	Sp.	Remarks.
	h.	m.	°	′			
+23° 123	0	48.9	+23	32	8.8	R	
..	6	34.1	+44	14	..	Md	Hγ and Hδ bright. Variable. H.V. 3373.
+14° 1598	7	7.2	+14	46	9.2	Rp	Hβ and Hγ bright. Variable. H.V. 3374.
−23° 5759		31.8	−23	22	11.6	N	
−26° 4942		42.2	−26	30	10.7	N	
..		42.5	−26	6	..	Md	Hγ and Hδ bright. Variable. H.V. 3375.
−28° 5249		55.7	−28	28	11.4	Oc	
−49° 3621	8	29.4	−49	16	7.3	B	Hβ bright.
..	11	27.6	−64	52	..	Pec.	Variable. H.V. 3376.
−34° 8125	12	18.9	−35	5	9.0	Mc	Variable. H.V. 3377.
..		57.9	−28	34	..	Md	Hγ and Hδ bright. Variable. H.V. 3378.
+42° 2811	17	10.4	+42	15	7.74	R	
+46° 2846	20	2.3	+46	24	8.8	B	Hβ bright.
− 3° 5751	23	57.0	− 3	23	9.9	R	

REMARKS.

h. m.

6 34.1. 063444. — Aurigae. This spectrum was found on a photograph taken April 22, 1914, with the 16-inch Metcalf Telescope. The variation was confirmed on five chart plates taken with the same instrument, which show that this star was about 12 magn. on December 12, 1912 and September 27, 1913,

h. m.

while on February 4 and February 18, 1913, it was invisible, and fainter than 14 magn. The period appears to be about 250 days.

7 7.2. 070714. — Geminorum. This spectrum was found on a photograph taken December 3, 1913, with the 16-inch Metcalf Telescope. Measures of its brightness have been made on 140 photographs, taken between February 22, 1891 and March 20, 1914. The variation is from 10.8 magn. to fainter than 14.9 magn. The period is about 377 days, but appears to be irregular.

7 42.5. *074226.* — Puppis. This spectrum was found on a photograph taken with the 8-inch Bache Telescope on April 21, 1914. The variation was confirmed on eleven photographic charts taken between December 16, 1895 and April 24, 1905. The range of variation is from 11.5 magn. to fainter than 15 magn.

11 27.6. *112764.* — Muscae. This spectrum was found on a photograph taken with the 8-inch Bache Telescope on May 1, 1908. It consists of four bright lines, which are Hβ, Hγ, Hδ, and probably 4653. The last line, which is faint, may be 4686. A variation of at least one magnitude was confirmed on nine photographic charts taken between June 10, 1896 and May 13, 1905. At maximum, the magnitude of the variable was estimated to be 0.8 fainter than C.P.D. −64° 1672, 9.7 magn.

12 18.9. *121835.* — Centauri. This spectrum was found on a photograph taken with the 8-inch Bache Telescope on June 3, 1910. The variation was confirmed on twelve photographic charts, taken between May 14, 1903 and January 25, 1909. At maximum, this star is equal to C. DM. − 35° 7907, 8.5 magn. At minimum, it is invisible on photographs taken with the Cooke lens showing stars of 11 magn.

12 57.9. *125728.* —Hydrae. This spectrum was found on a photograph taken with the 8-inch Bache Telescope on June 1, 1910. The variation was confirmed on ten photographs taken between April 8, 1892, and March 18, 1911. At maximum, the variable is equal to C.P.D. − 28° 4612, 9.5 magn. At minimum, it is invisible and fainter than 14 magn.

Table II gives a continuation of the list of stars having composite spectra. The first four columns contain the Durchmusterung number, the right ascension for 1900, the declination for 1900, and the photometric magnitude or the Durchmusterung magnitude reduced to the photometric scale, the latter being carried to tenths only. In the case of stars south of −52°, the magnitude according to the Cape Photographic Durchmusterung is given. The fifth column gives the number in Burnham's "General Catalogue of Double Stars," when the star is contained in that work. The sixth and seventh columns give the class of spectrum of the brighter and fainter components, as they are determined from the general appearance of the blended spectrum.

TABLE II.

STARS HAVING COMPOSITE SPECTRA. 24 NEW DOUBLE STARS.

DM.	R. A. 1900.		Dec. 1900.		Magn.	Burnham.	Br.	Ft.
	h.	m.	°	′				
+51° 153	0	43.0	+51	33	6.84	..	F8	A3
+17° 1483	6	57.6	+17	0	9.9	..	F5	A0
− 1° 1612	7	9.8	− 1	12	7.9	..	G0	A3
−10° 2126		31.9	−10	25	8.0	..	F5	A2
− 3° 2061		41.7	− 3	38	8.1	..	G0	A2
− 8° 2186		56.9	− 8	19	7.21	..	F5	A2
−41° 3694	8	0.0	−41	54	10.6	..	F5	A2

DM.	R. A. 1900.		Dec. 1900.		Magn.	Burnham.	Br.	Ft.
	h.	m.	°	′				
−26° 5599	8	5.5	−26	36	9.4	..	F5	A
−19° 2369		16.9	−19	46	5.56	..	G0	A3
−26° 6417		41.9	−26	14	7.32	..	K0	A3
−16° 2589		42.8	−16	41	6.62	4783	G0	A2
−36° 5125		48.8	−36	10	6.54	..	F5	A3
− 8° 2518		49.4	− 8	23	7.42	4849	F0	A2
−39° 4924		50.1	−40	4	6.46	..	K0	A5
−25° 6966	9	8.0	−25	11	7.36	..	F5	A2
− 2° 2906		24.6	− 2	41	7.8	5114	F5	A3
−70° 1047	10	18.6	−70	40	8.6	..	F5	A2
−23° 9339		26.4	−23	40	7.7	..	F5	A3
−57° 3663		37.0	−57	25	8.1	..	F5	A
−52° 3929		44.3	−52	20	9.4	..	F2	A3
−53° 4215		49.6	−53	23	8.8	..	G0	A2
−26° 8272		54.6	−26	14	8.1	..	F5	A2
−65° 1649	11	11.3	−65	58	8.8	..	K0	A2
−58° 3551		18.8	−59	2	9.0	..	F5	A3
−51° 5895		34.4	−51	20	8.8	..	G0	A3
−27° 8287		40.4	−27	49	8.4	..	F2	A3
−53° 4756		41.5	−53	37	8.4	..	F5	A3
+29° 2508	14	9.4	+29	35	6.76	6772	F0	A2
+52° 2258	18	36.6	+52	14	6.86	8732	F2	A3
+11° 3955	19	37.9	+11	35	5.32	9531	F5	A3
+11° 3994		44.0	+11	34	5.70	9634	F2	A2

Including those in Table II, one hundred stars with composite spectra have been found on the Harvard photographs. Of the forty-five brighter ones, which were published in H.A. 28, 93, 229 and H.A. 56, 113, 160, twenty-five, or 0.56, are known to be double, either visually or spectroscopically. Of the fifty-five published here and in H. C. 178, only eleven, or 0.20 are known to be double. It is probable that many of these will be found to be spectroscopic binaries.

EDWARD C. PICKERING.

September 29, 1914.

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HARVARD COLLEGE OBSERVATORY.

CIRCULAR 185.

A SECOND HARVARD MAP OF THE SKY.

In H.C. 71, a description is given of a photographic map of the entire sky. This map consists of double contact prints on glass of 55 photographs, taken with anastigmatic lenses, each having an aperture of one inch and a focal length of about thirteen inches. One camera was mounted in Cambridge and was used principally for the northern stars, the other, mounted at Arequipa, was similarly used for the southern stars. Each of the prints consists of a glass plate eight by ten inches, and includes a region 30° square. The value of these plates has been greatly increased by a count of the stars on them by Dr. H. Henie of Upsala, Sweden (Medd. Lunds Astron. Observ. Series 2, No. 10). It appears that the total number of stars shown is 1,683,000, and the limiting magnitude is about 11.5.

A wide distribution has been made of these plates, which have been sold at $15.00, a price somewhat less than cost. The second set, described below, will be sold for the same price. Many more stars would be shown on plates having a longer exposure as is illustrated by the map of the Milky Way printed in H. A. 72, No. 3, but in many parts of the sky the stars are so crowded that they are not readily distinguished from one another. Two difficulties arise in the use of these plates. Many defects appear which may at first be mistaken for stars. They can generally be distinguished with certainty by a microscope. Some defects in the second set, appearing more or less like stars, have been removed. Their positions can be recognized by transparent spots on the plate. Owing to the large area covered, the images of stars near the corners are distorted, and faint stars do not appear there. Accordingly, a second series of 60 plates has been selected and another map of the sky has been prepared by Professor King. The centres of these plates coincide so far as possible with the corners of the others. The declinations of the centres of the first set are 0°, 30°, 60° and 90°, of the second 15°, 45°, and 75°. An exception was made of the South Pole which is so low at Arequipa that two plates were used having declinations −85° and −75°. They are Nos. 54 and 55 in the first set.

A list of all the plates is given in Table I. The number designating the plate is given in the first column. It should be preceded by the letters H.M. denoting Harvard Map. Numbers 1 to 55 form the first set, numbers 56 to 115, the second. The approximate right ascension and declination of the centre of the plate are given in the second and third columns. The designation of the original negative is given in the fourth column. It consists of the letters indicating the series, and the number of the plate in that series. Plates taken in Cambridge are indicated by the letters AC, those at Arequipa by AM. The date, the Greenwich Mean time following Greenwich noon, and the length of exposure, are given in the next three columns.

TABLE I.

CATALOGUE OF PLATES.

H.M.	R. A.	Dec.	Negative.	Date.	G. M. T.	Ex.
	h. m.	°			h. m.	m.
1	0 00	+90	AC 2161	02, Jan. 4	22 43	39
2	0 00	+60	AC 1943	01, Nov. 2	17 51	63
3	3 00	“	AC 3924	03, Sept. 12	16 14	69
4	6 00	“	AC 3933	03, Sept. 13	19 52	93
5	9 00	“	AC 3625	03, May 13	13 16	59
6	12 00	“	AC 3466	“ Mar. 31	18 42	71
7	15 00	“	AC 3620	“ May 12	14 51	58
8	18 00	“	AC 3629	“ “ 13	18 14	70
9	21 00	“	AC 3630	“ “ 13	19 25	60
10	0 00	+30	AC 2152	02, Jan. 4	13 06	57
11	2 00	“	AC 124	98, Dec. 16	13 09	62
12	4 00	“	AC 2155	02, Jan. 4	16 16	59
13	6 00	“	AC 3469	03, April 1	12 48	75
14	8 00	“	AC 3363	“ Feb. 26	16 16	59
15	10 00	“	AC 2160	02, Jan. 4	21 55	56
16	12 00	“	AC 3332	03, Feb. 20	21 04	67
17	14 00	“	AC 1105	00, Dec. 28	22 04	68
18	16 00	“	AC 252	99, Mar. 20	20 19	64
19	18 00	“	AC 1013	00, Sept. 24	12 12	56
20	20 00	“	AC 3353	03, Feb. 23	22 03	62
21	22 00	“	AC 1014	00, Sept. 24	13 16	69
22	0 00	0	AM 1569	02, “ 25	15 32	58
23	2 00	“	AM 151	99, “ 14	18 45	60
24	4 00	0	AC 1093	00, Dec. 27	13 27	71
25	6 00	“	AC 2156	02, Jan. 4	17 22	73
26	8 00	“	AC 513	99, Nov. 9	22 01	64
27	10 00	“	AC 2518	02, May 2	14 19	65
28	12 00	“	AM 1431	“ July 8	12 09	65
29	14 00	“	AC 2547	“ May 13	16 35	73
30	16 00	“	AM 1420	“ July 3	13 15	60
31	18 00	“	AM 1436	“ “ 9	14 18	60
32	20 00	“	AM 1439	“ “ 9	17 30	60
33	22 00	“	AM 1441	“ “ 9	19 39	60
34	0 00	−30	AM 1427	“ “ 3	20 53	60
35	2 00	“	AM 1451	“ “ 10	20 56	61
36	4 00	“	AM 1802	03, Jan. 16	15 55	68
37	6 00	“	AM 1785	“ “ 3	17 33	60
38	8 00	“	AM 1798	“ “ 15	16 35	60
39	10 00	“	AM 1419	02, July 3	12 01	61
40	12 00	“	AM 1443	“ “ 10	12 07	67
41	14 00	“	AM 1444	“ “ 10	13 15	60
42	16 00	“	AM 1452	“ “ 11	14 39	60
43	18 00	“	AM 1461	“ “ 12	14 37	60
44	20 00	“	AM 1463	“ “ 12	17 26	61
45	22 00	“	AM 1440	“ “ 9	18 36	61
46	0 00	−60	AM 703	00, Nov. 1	13 37	61

H.M.	R. A.	Dec.	Negative.	Date.	G. M. T.	Ex.	H.M.	R. A.	Dec.	Negative.	Date.	G. M. T.	Ex.
	h. m.	°			h. m.	m.		h. m.	°			h. m.	m.
47	3 00	−60	AM 1782	03, Jan. 3	14 12	64	82	17 00	+15	AC 4922	04, May 21	17 58	62
48	6 00	"	AM 712	00, Nov. 10	18 33	60	83	19 00	"	AM 2935	" Aug. 10	16 30	62
49	9 00	"	AM 1247	02, May 15	12 43	60	84	21 00	"	AM 3813	05, " 19	17 42	65
50	12 00	"	AM 459	00, " 8	15 10	72	85	23 00	"	AC 6931	" Nov. 2	14 02	71
51	15 00	"	AM 1469	02, July 14	14 13	60	86	1 00	−15	AM 2918	04, Aug. 4	18 14	60
52	18 00	"	AM 809	01, May 27	17 48	61	87	3 00	"	AM 3772	05, " 9	21 18	62
53	21 00	"	AM 1464	02, July 12	18 32	60	88	5 00	"	AM 2345	03, Oct. 21	18 48	60
54	0 00	−85	AM 626	00, Sept. 3	17 11	60	89	7 00	"	AM 3237	04, Nov. 16	18 34	60
55	14 00	−75	AM 1389	02, June 25	15 13	60	90	9 00	"	AM 4105	06, Feb. 14	17 43	60
56	2 00	+75	AC 12193	10, Dec. 9	14 14	60	91	11 00	"	AM 1816	03, " 5	19 51	63
57	6 00	"	AC 4714	04, Mar. 8	15 46	83	92	13 00	"	AM 2622	04, May 6	13 58	62
58	10 00	"	AC 4716	" " 8	18 13	62	93	15 00	"	AM 1827	03, Feb. 20	19 30	60
59	14 00	"	AC 3154	03, Jan. 9	22 12	68	94	17 00	"	AM 2669	04, May 23	16 08	60
60	18 00	"	AC 1959	01, Nov. 6	14 28	60	95	19 00	"	AM 2907	" Aug. 2	16 58	60
61	22 00	"	AC 5484	04, " 5	12 52	85	96	21 00	"	AM 1307	02, June 5	21 08	60
62	1 00	+45	AC 1977	01, " 10	15 24	64	97	23 00	"	AM 2759	04, " 18	20 15	60
63	3 00	"	AC 163	99, Jan. 18	13 16	68	98	1 00	−45	AM 2869	" July 22	19 05	60
64	5 00	"	AC 5514	04, Nov. 11	19 35	60	99	3 00	"	AM 2920	" Aug. 4	20 17	60
65	7 00	"	AC 1263	01, Feb. 19	15 03	64	100	5 00	"	AM 2240	03, " 31	20 12	60
66	9 00	"	AC 6118	05, Mar. 4	16 14	65	101	7 00	"	AM 2424	" Dec. 23	17 44	60
67	11 00	"	AC 6072	05, Feb. 26	19 28	63	102	9 00	"	AM 2621	04, May 6	12 54	61
68	13 00	"	AC 2515	02, May 1	16 38	74	103	11 00	"	AM 1824	03, Feb. 20	16 18	62
69	15 00	"	AC 11549	10, April 1	19 56	62	104	13 00	"	AM 1988	" June 2	15 13	61
70	17 00	"	AC 5054	04, July 13	16 20	88	105	15 00	"	AM 1999	" " 3	16 18	60
71	19 00	"	AC 10266	09, Feb. 25	21 48	60	106	17 00	"	AM 833	01, " 6	17 38	70
72	21 00	"	AC 4040	03, Oct. 14	15 13	62	107	19 00	"	AM 2694	04, " 2	18 18	60
73	23 00	"	AC 5374	04, " 16	14 34	78	108	21 00	"	AM 982	01, Aug. 10	17 11	65
74	1 00	+15	AC 7029	05, Nov. 21	14 28	75	109	23 00	"	AM 2768	04, June 20	20 12	61
75	3 00	"	AC 5642	04, Dec. 1	16 24	68	110	2 00	−75	AM 3323	05, Jan. 13	14 10	62
76	5 00	"	AC 13679	13, Jan. 25	13 56	60	111	6 00	"	AM 3244	04, Nov. 17	17 11	79
77	7 00	"	AC 12789	11, Dec. 13	20 08	60	112	10 00	"	AM 2730	" June 8	12 33	61
78	9 00	"	AC 7208	06, Jan. 25	19 02	66	113	14 00	"	AM 2700	" " 3	15 00	60
79	11 00	"	AC 11434	10, Mar. 4	17 31	60	114	18 00	"	AM 2765	" " 20	17 02	61
80	13 00	"	AC 11436	" " 4	19 32	60	115	22 00	"	AM 4522	06, Aug. 23	17 50	65
81	15 00	"	AC 6243	05, April 1	18 13	58							

It is proposed to continue this series, from time to time, if it should prove desirable.

EDWARD C. PICKERING.

NOVEMBER 13, 1914.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 186.

OBSERVATIONS OF SZ TAURI.

An investigation of the light curve of the short period variable SZ Tauri has been made by Miss Leavitt, who has prepared the summary of the results given below.

Elements of this variable, based on observations by Professor Hertzsprung were published by Professor Schwarzschild in 1911, A. N. 189, 346. The times of minima, as derived from measures on 103 photographs taken between January, 1906, and March, 1911, were found to be represented by the formula, J. D. 2,418,724.16 M.E.Z. + $3^{d}.1484$ E. In order to obtain a more precise period, if possible, 210 plates taken at this Observatory between October, 1891, and February, 1914, have been examined. The greater number of the observations were made before the publication of Professor Schwarzschild's article, but the comparison stars selected were the same as those employed by him. In Table I, the successive columns give the designation, the number in the Bonn Durchmusterung, the right ascension for 1900, the declination for 1900, the photometric magnitude, a provisional photographic magnitude, and the spectrum as classified by Miss Cannon. Absolute magnitudes on the scale of the North Polar Sequence have not been obtained, and the observations can be used only for correcting the period, not for a precise study of the changes of light.

TABLE I.

COMPARISON STARS.

Des.	DM.	R. A. 1900.			Dec. 1900.		Ptm.	Prov. Ptg.	Sp.
		h.	m.	s.	°	'			
Var.	+18° 661	4	31	26	+18	20.4	6.64	..	G0
a	+19° 742	4	29	51	+19	40.5	6.56	7.0	F8
b	+19° 744	4	30	43	+19	33.3	..	7.5	A2
c	+18° 684	4	37	1	+18	32.0	7.12	7.8	G5

HARVARD COLLEGE OBSERVATORY.

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OBSERVATIONS OF SZ TAURI.

An investigation of the light curve of the short period variable SZ Tauri has been made by Miss Leavitt, who has prepared the summary of the results given below.

Elements of this variable, based on observations by Professor Hertzsprung were published by Professor Schwarzschild in 1911, A. N. 189, 346. The times of minima, as derived from measures on 103 photographs taken between January, 1906, and March, 1911, were found to be represented by the formula, J. D. 2,418,724.16 M.E.Z. + $3^d.1484$ E. In order to obtain a more precise period, if possible, 210 plates taken at this Observatory between October, 1891, and February, 1914, have been examined. The greater number of the observations were made before the publication of Professor Schwarzschild's article, but the comparison stars selected were the same as those employed by him. In Table I, the successive columns give the designation, the number in the Bonn Durchmusterung, the right ascension for 1900, the declination for 1900, the photometric magnitude, a provisional photographic magnitude, and the spectrum as classified by Miss Cannon. Absolute magnitudes on the scale of the North Polar Sequence have not been obtained, and the observations can be used only for correcting the period, not for a precise study of the changes of light.

TABLE I.

COMPARISON STARS.

Des.	DM.	R. A. 1900.	Dec. 1900.	Ptm.	Prov. Ptg.	Sp.
		h. m. s.	° ′			
Var.	+18° 661	4 31 26	+18 20.4	6.64	. .	G0
a	+19° 742	4 29 51	+19 40.5	6.56	7.0	F8
b	+19° 744	4 30 43	+19 33.3	. .	7.5	A2
c	+18° 684	4 37 1	+18 32.0	7.12	7.8	G5

The observations of the variable are given in Table II. Four instruments were employed in taking the photographs, namely, the 0.5-inch Ross-Zeiss Telescope, the 1-inch Cooke Telescopes at Cambridge and at Arequipa, and the 8-inch Draper Telescope. These are designated respectively by the letters g, c, f, and i, following the Julian Day and decimal expressed in Greenwich Mean Time, as given in the first column.

Direct estimates of the brightness of the variable were made on each plate, to the nearest tenth of a magnitude, assuming the provisional magnitudes of the comparison stars. On plates taken with the 8-inch Draper Telescope, the images formed by the auxiliary prism were employed, as the principal images are too bright. On the plate taken on J. D. 2742, the images are followed by long trails, whose relative intensities were estimated.

Nearly all of the estimates were repeated at a later time, reversing the position of the plate. The mean of these estimated magnitudes is given in the second column. The average deviation from the mean is ±0.06 magn.

When the observations were reduced by the formula given on the first page, it was found that those on plates taken earlier than the year 1903 were not satisfied. All of the observations can be well represented by the formula, for times of maximum, J. D. 2,410,000.60 G. M. T. + $3^d.1487$ E, which was used in computing the epochs and phases given in the third and fourth columns. Normal points were formed by taking the means of five successive phases and the corresponding magnitudes. The resulting light curve is given in Figure 1, in which the horizontal scale is 1 day = 1.0 cm., and the vertical scale is 0.2 magn. = 1.0 cm. The residuals of individual magnitudes from this curve are given in the last column of Table II. The average deviation is ±0.061 magn. for the 210 plates. Omitting 9 residuals greater than 0.14 magn. would reduce this to ±0.055 magn. In order to correct the period, residuals were taken in hundredths of a day for magnitudes between 7.23 and 7.40, inclusive, when the light was changing most rapidly. The means of successive groups of five were then taken, in the order of the epochs, omitting observations for which the residual given in the last column, is greater than 0.14 magn. In Figure 2 abscissas represent the means of the five epochs, and ordinates the means of the corresponding residuals. The horizontal and ver-

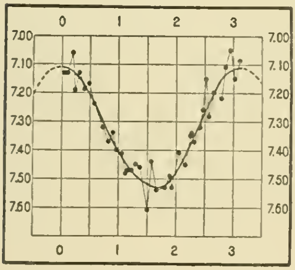

Fig. 1.

tical scales are 500 epochs = 1.0 cm., and 0.50 days = 1.0 cm., respectively. Each of the first two points comprises only two observations, and includes the magnitudes 7.20 and 7.45. It is evident that, owing to the small range of the variable and the difficulty of estimating the magnitude of so bright an object, the observations are not sufficiently precise to permit a further correction of the period. The last unit of the formula given above appears, however, to be well established.

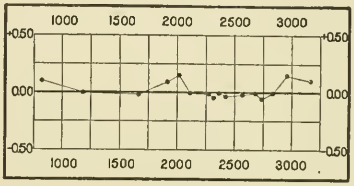

Fig. 2.

TABLE II.

OBSERVATIONS OF THE VARIABLE.

J. D.	Magn.	E.	Phase.	Res.	J. D.	Magn.	E.	Phase.	Res.	J. D.	Magn.	E.	Phase.	Res.
2034.838i	6.90	645	0.178	*22*	6134.666g	7.13	1947	0.400	*04*	6471.525g	7.13	2054	0.347	*03*
2077.717i	7.45	658	2.123	01	6136.641g	7.37	1948	1.552	*15*	“ .667g	7.20	“	0.489	00
2103.616i	7.15	666	2.834	01	6155.631g	7.40	1954	2.472	11	6472.719g	7.63	“	1.541	10
2114.591i	7.50	670	1.214	03	6159.663g	7.17	1954	0.208	04	6476.764g	7.37	2055	2.437	07
2742.825i	6.90	869	2.856	*24*	6165.590g	7.10	1956	2.986	*02*	6477.680g	7.03	“	0.205	*10*
2808.619i	7.05	890	2.527	*21*	6168.583e	7.30	1957	2.831	16	6484.681g	7.52	2058	0.909	15
3148.730i	7.35	998	2.579	11	6169.591g	7.27	1958	0.690	*01*	6494.705g	7.53	2061	1.487	01
3169.623i	7.60	1005	1.431	09	6176.605g	7.40	1960	1.405	*10*	6514.610e	7.27	2067	2.499	*01*
3560.741i	7.45	1130	2.110	01	6186.601g	7.67	1963	1.954	18	6519.582e	7.43	2069	1.173	*03*
3826.733i	7.20	1214	0.463	01	6189.572g	7.6	1964	1.776	07	6738.868f	7.15	2139	0.050	04
3841.756i	7.00	1218	-2.891	*13*	6358.887f	7.43	2018	1.063	01	6743.789f	7.40	2140	1.823	*12*
3855.748i	7.50	1223	1.139	05	6382.865g	7.13	2026	2.999	01	6768.770f	7.47	2148	1.615	*06*
4941.718f	7.30	1568	0.808	*03*	6402.811f	7.30	2032	0.904	*07*	6774.772f	7.43	2150	1.319	*06*
4954.787f	7.40	1572	1.281	*08*	6414.708f	7.17	2036	0.206	04	6796.743f	7.40	2157	1.249	*08*
4956.784f	7.20	1573	0.130	08	6416.758g	7.40	2037	2.256	03	6801.687f	7.00	2158	3.044	*11*
4991.691f	7.23	1584	0.402	06	6418.782g	7.50	“	1.132	05	6813.692f	7.27	2162	2.455	*02*
5282.875f	7.50	1677	1.905	*01*	6422.758g	7.55	2038	1.958	06	6820.738f	7.13	2165	0.053	02
5309.877f	7.27	1685	0.568	03	6429.765g	7.20	2040	2.669	00	7069.836e	7.15	2244	0.405	*02*
5724.665f	7.13	1816	2.877	00	6433.733g	7.17	2042	0.339	01	7097.849e	7.15	2253	0.078	04
5791.587e	7.07	1838	0.528	*15*	6438.725g	7.60	2043	2.182	19	7102.763e	7.60	2254	1.845	08
5985.855f	7.27	1899	2.726	10	6439.731g	7.10	“	0.040	*01*	7117.849f	7.43	2258	1.187	*03*
6029.863f	7.23	1913	2.652	03	6443.711g	7.30	2045	0.871	*05*	7123.758e	7.35	2261	0.798	02
6030.762f	7.27	1914	0.402	10	6447.762g	7.40	2046	1.773	*13*	7125.891e	7.05	“	2.931	*07*
6033.747f	7.13	1915	0.239	00	6455.703g	7.13	2049	0.268	*01*	7128.806f	7.23	2263	2.699	05
6034.802f	7.37	1915	1.294	*12*	6459.827g	7.50	2050	1.244	03	7133.746e	7.48	2264	1.341	*02*
6104.623g	7.63	1938	1.842	11	6462.837g	7.55	2051	1.104	13	7151.873e	7.15	2270	0.577	*08*
6112.638g	7.17	1940	0.412	*01*	6464.725g	7.2	2051	2.993	08	7152.861e	7.43	2270	1.565	*10*

J. D.	Magn.	E.	Phase.	Res.	J. D.	Magn.	E.	Phase.	Res.	J. D.	Magn.	E.	Phase.	Res.
7159.842e	7.30	2272	2.248	*09*	7977.595f	7.47	2532	1.338	*03*	8962.775e	7.30	2845	0.975	*10*
7161.798e	7.40	2273	1.056	*02*	7994.545e	7.12	2537	2.545	*13*	8973.823e	7.30	2848	2.577	06
7194.725e	7.23	2283	2.494	*05*	8181.809e	7.37	2597	0.886	01	8984.757e	7.40	2852	0.916	02
7208.660f	7.20	2288	0.686	*07*	8209.816f	7.17	2606	0.555	*06*	8987.783e	7.45	2853	0.794	08
7216.604e	7.40	2290	2.332	06	8251.824e	7.56	2619	1.630	03	8988.740e	7.60	2853	1.751	07
7221.671e	7.40	2292	1.103	*04*	8269.660f	7.20	2625	0.574	*03*	9008.779e	7.05	2860	2.898	*08*
7237.660e	7.54	2297	1.348	04	8277.646e	7.37	2627	2.263	*01*	9018.678e	7.10	2863	0.202	*03*
7238.575e	7.30	2297	2.262	*08*	8291.791e	7.20	2632	0.664	*07*	9028.675e	7.25	2866	0.753	*05*
“ .576f	7.3	“	2.263	*08*	8299.678e	7.27	2634	2.253	*11*	9033.652e	7.20	2868	2.581	*04*
7257.565f	7.37	2303	2.359	04	8308.715e	7.56	2637	1.845	04	9042.664e	7.35	2871	2.146	*07*
7258.588e	7.13	2304	0.234	00	8339.622e	7.55	2647	1.265	07	9084.545e	7.25	2884	3.094	14
7276.568e	7.23	2309	2.471	*06*	8344.614e	7.17	2648	3.108	04	9326.783e	7.25	2961	2.882	12
7282.528e	7.46	2311	2.133	03	8347.613f	7.00	2650	2.959	*12*	9339.910e	7.25	2966	0.265	11
7284.553e	7.48	2312	1.010	07	8351.546e	7.23	2651	0.594	*01*	9344.784e	7.55	2967	1.990	07
7287.534e	7.37	2313	0.843	03	8367.547e	7.33	2656	0.851	*01*	9381.744e	7.45	2978	1.166	*02*
7295.537e	7.27	2315	2.549	02	8374.512e	7.73	2658	1.519	21	9412.656e	7.25	2989	0.591	01
7302.533e	7.03	2318	0.099	*10*	8381.551e	7.35	2660	2.260	*03*	9443.540e	7.10	2998	3.137	*01*
7314.531e	7.20	2321	2.650	00	8573.845f	7.17	2721	2.483	*11*	9449.538e	7.25	3000	2.838	11
7444.883f	7.30	2363	0.756	00	8575.802f	7.50	2722	1.292	01	9461.516e	7.45	3004	2.221	05
7482.827e	7.47	2375	0.918	09	8580.891e	7.13	2724	0.083	02	9472.514e	7.15	3008	0.624	*10*
7496.790f	7.33	2379	2.284	*04*	8591.875f	7.43	2727	1.622	*10*	9682.903e	7.10	3075	0.050	*03*
7498.846e	7.53	2380	1.192	07	8598.807e	7.32	2729	2.256	*10*	9690.873e	7.55	3077	1.723	02
7501.809f	7.40	2381	1.007	*01*	8599.851e	7.13	2730	0.152	01	9692.857e	7.35	3078	0.558	12
7521.717e	7.53	2387	2.022	06	8600.781f	7.40	“	1.082	*03*	9696.852e	7.40	“	1.404	*11*
7528.771e	7.13	2389	2.779	*03*	8601.879e	7.38	“	2.179	*03*	9710.856e	7.0	3083	2.813	*14*
7534.728e	7.33	2391	2.437	03	8605.862e	7.13	2731	3.015	01	9721.702f	7.50	3087	1.064	08
7541.783f	7.13	2394	0.047	02	8618.756e	7.10	2736	0.165	*02*	9724.796e	7.3	3088	1.009	*11*
7552.749e	7.47	2397	1.567	*06*	8623.801f	7.33	2737	2.060	*13*	9725.679f	7.55	“	1.892	04
7558.651f	7.47	2399	1.171	*01*	8646.779f	7.10	2744	2.998	*02*	9738.729e	7.45	3092	2.347	12
7585.673e	7.26	2408	3.004	14	8647.810e	7.30	2745	0.880	*07*	9767.689e	7.1	3101	2.971	*02*
7598.659e	7.27	2412	0.245	13	8652.712f	7.13	2747	2.634	*08*	20076.821e	7.10	3200	0.381	*06*
7616.606e	7.23	2417	2.449	*06*	8662.677e	7.13	2750	0.004	02	20078.836e	7.40	“	2.396	08
7619.580e	7.37	2418	2.274	00	8671.437e	7.10	2753	2.467	*19*	20092.785e	7.25	3205	0.601	01
7792.916f	7.27	2473	2.432	*03*	8680.643e	7.47	2755	2.226	07	20094.758e	7.30	3205	2.574	06
7793.898f	7.13	2474	0.266	*01*	8682.680e	7.40	2756	1.115	*04*	20105.735e	7.45	3209	0.956	*04*
7864.809f	7.48	2496	1.905	*01*	8708.660e	7.50	2764	1.904	*01*	20107.707e	7.33	“	2.928	20
7870.746e	7.45	2499	1.544	*07*	8740.523e	7.30	2774	2.281	*07*	20110.746e	7.25	3210	2.818	11
7877.849f	7.30	2500	2.349	*04*	8742.524e	7.57	2775	1.133	09	20130.684e	7.35	3217	0.715	06
7882.837f	7.33	2502	1.041	*09*	8749.572e	7.45	2778	1.884	*06*	20131.655e	7.55	“	1.686	02
7883.828e	7.35	“	2.032	*12*	8756.527e	7.23	2780	2.542	*03*	20151.629e	7.37	3223	2.768	21
7944.744e	7.00	2521	3.123	*11*	8896.837e	7.48	2824	1.158	03	20155.592e	7.20	3225	0.433	02
7949.604e	7.53	2523	1.686	00	8944.849e	7.55	2839	1.942	05	20179.543e	7.50	3232	2.345	14
7971.635e	7.53	2530	1.676	00	8954.872e	7.15	2842	2.519	*11*	20188.501e	7.40	3235	1.857	*12*

EDWARD C. PICKERING.

November 14, 1914.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 187.

CAMPBELL'S COMET, 1914 e.

THIS comet appears to have been first seen on Thursday, September 17 (astronomical date), at one o'clock in the morning, by Mr. Leon Campbell, Assistant in charge of the Arequipa Station of the Harvard Observatory. The comet was then visible to the naked eye. It was discovered independently a few hours later by Mr. Lunt at the Cape Observatory, and by Mr. Westland in New Zealand.

Six photographs were taken by Mr. Campbell with the 8-inch Bache Telescope. They have just reached Cambridge and have been measured by Miss A. D. Walker. In Table I, the successive columns give the calendar date, the Julian Day and decimal, the right ascension and declination for 1875.

TABLE I.

POSITIONS OF COMET.

Date.			Julian Day.	R. A. 1875.			Dec. 1875.	
				h.	m.	s.	°	′
1914	September	17	2420393.801	4	26	7.5	−57	16.4
"	"	"	0393.805	4	26	2.1	−57	16.7
"	"	18	0394.727	3	55	49.2	−57	54.3
"	"	"	0394.762	3	54	46.1	−57	55.0
"	"	"	0394.772	3	54	23.3	−57	55.3
"	"	21	0397.651	2	8	35.7	−56	21.6
"	"	"	0397.659	2	8	13.0	−56	20.7
"	"	23	0399.598	1	3	20.8	−52	3.0
"	"	"	0399.608	1	3	3.4	−52	0.0
"	"	"	0399.644	1	1	49.7	−51	54.9

Owing to the size and haziness of the photographic images approximate positions only are given. The positions of the comparison stars are taken from the Cape Photographic Durchmusterung. Each image was compared with three stars, the average deviation of the results being ±1ˢ.1 in right ascension, and ±0′.1 in declination.

EDWARD C. PICKERING.

JANUARY 27, 1915.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 188.

THE COLOR INDEX OF S CEPHEI.

THE following study of the color index of S Cephei, has been made by Miss H. S. Leavitt.

One of the most valuable results of the long series of visual observations of variable stars made at this Observatory, and elsewhere, will be obtained when they can be compared with observations on contemporary photographs. For this purpose, an absolute scale of photographic magnitudes is necessary, and observations published before the adoption of the magnitudes of the stars in the North Polar Sequence, described in H.A. 71, No. 3, cannot be used without correction. For many long period variables we have now the material for comparison of visual and photographic magnitudes in all parts of the light curve. In 1896, many photographic observations were made for the 17 Circumpolar Variables discussed in H.A. 37, Part 1. Many of these could be seen on plates exposed 10 minutes with the 8-inch Draper Telescope, even when near minimum. It was found impossible to identify S Cephei with certainty on any plate, although its visual range, from about the eighth to the thirteenth magnitudes, was such that had it been no redder than other variables, T Ursae Majoris for example, it would have been easily photographed even when near minimum.

In 1897, a special effort was made to follow this variable, both visually and photographically, and 19 plates showing it clearly were obtained. Several attempts to obtain its spectrum on ordinary plates were unsuccessful, as no indication of its presence could be seen even when near maximum. A photograph on a plate stained with erythrosine and exposed through a yellow screen showed a conspicuous image having all the light concentrated near wave length 5600. Dunér gives the spectrum as of Type IV!! The observations in 1897, with a few on later plates, are given in Table I. The successive columns give the Julian Day, the length of exposure, the observed photographic magnitude on the scale of H.A. 71, No. 3, the visual magnitude read from a smooth curve, and the difference between the two. All the photographs were taken with

TABLE I.

MAGNITUDE AND COLOR INDEX.

J. D.	Exp.	Ptg.	Vis.	Color Index.	J. D.	Exp.	Ptg.	Vis.	Color Index.	J. D.	Exp.	Ptg.	Vis.	Color. Index.
	m.					m.					m.			
13932	34	14.48	8.38	6.1	14056	11	12.82	7.87	5.0	14223	24	14.50	9.02	5.5
13951	48	14.26	8.16	6.1	14063	18	12.62	7.90	4.7	15654	21	<13.9	8.48	>5.4
13984	48	13.72	7.88	5.8	14070	16	12.88	7.90	5.0	16007	20	13.37	8.35	5.0
14009	28	13.24	7.73	5.5	14076	16	12.82	7.89	4.9	16090	27	<14.0	8.07	>5.9
14032	59	12.92	7.70	5.2	14077	10	12.88	7.88	5.0	16412	20	14.7?	8.56	6.1
14044	22	12.88	7.76	5.1	14092	11	12.82	7.82	5.0	16416	40	15.00	8.50	6.5
14049	22	12.78	7.80	5.0	14094	11	12.78	7.81	5.0	19999	10	<12.8	7.8	>5.0
14051	9	12.88	7.81	5.1	14097	10	12.78	7.81	5.0	20333	10	<16.0	10.8	>5.2
14052	10	12.82	7.81	5.0	14140	20	13.09	8.16	4.9	20391	10	<16.0	10.0	>6.0

the 8-inch Draper Telescope except the last three, of which that taken on J. D. 19999 was photographed with the 4-inch Cooke Anastigmat, and the two last with the 16-inch Metcalf Telescope. The color equations of various visual observers differ by a magnitude or more for this star, and in themselves might be used to determine its color index. Fortunately, two observers, Mr. W. M. Reed and Miss A. J. Cannon, agree very closely in their sensitiveness to color and each made a large number of observations in 1897. The magnitudes in the fourth column, when given to hundredths, were read from a smooth curve depending on their estimates alone, as given in H.A. 37, Part 1. The magnitudes on the last three lines depend on observations by various persons, and are uncertain on account of unknown personal equations. The color indices in the last column are extremely large. They vary by about a magnitude, and it seems probable that there is a real difference depending on the phase. This is more clearly brought out in Table II in which the magnitudes, as read from smooth curves, are given for every 20 days for the period covered by photographs taken in 1897. The four columns give the Julian Day, the photographic and visual magnitudes, and the difference between the two. While the visual brightness increased half a magnitude between J.D. 13940 and J.D. 14100, the photographic brightness increased a magnitude and a half. The corresponding color indices are six magnitudes and five magnitudes, respectively. The color index again grows larger after maximum has been passed, but apparently the change in color progresses more slowly. These differences cannot be ascribed wholly to errors of obser-

TABLE II.

COORDINATES OF LIGHT CURVES IN 1897.

J. D.	Ptg.	Vis.	Color Index.	J. D.	Ptg.	Vis.	Color Index.	J. D.	Ptg.	Vis.	Color Index.
13940	14.38	8.29	6.09	14040	12.88	7.76	5.12	14140	13.09	8.16	4.93
13960	14.09	8.09	6.00	14060	12.80	7.89	4.91	14160	13.43	8.37	5.06
13980	13.76	7.90	5.86	14080	12.86	7.87	4.99	14180	13.73	8.56	5.17
14000	13.40	7.77	5.63	14100	12.80	7.83	4.97	14200	14.08	8.78	5.30
14020	13.09	7.70	5.39	14120	12.90	7.97	4.93	14220	14.44	9.00	5.44

vation, as the light curves are well defined, especially for the plates preceding and during maximum.

The visual and photographic observations are shown in Figure 1. Horizontal and vertical distances represent Julian Days on a scale of 100 days = 1 cm., and 1 magn. = 1 cm., respectively. Visual observations by Mr. Reed and Miss Cannon are represented by dots and open circles respectively, and are seen to be in good agreement. Observations on photographs are also represented by dots but occur in a much fainter part of the scale. The large color index is strikingly indicated by the wide blank space separating the two kinds of observations. Usually the visual and photographic light curves of long period variables come near together, showing color indices of from one to two magnitudes. To obtain the true color indices for various phases of S Cephei, the visual magnitudes represented in Figure 1 require correction for color equation to the standard system, but the corresponding photographic observations require little if any correction, as the color equation of the 8-inch Draper Telescope is nearly 1.0 magn., on the scale proposed in H.A. 71, 226.

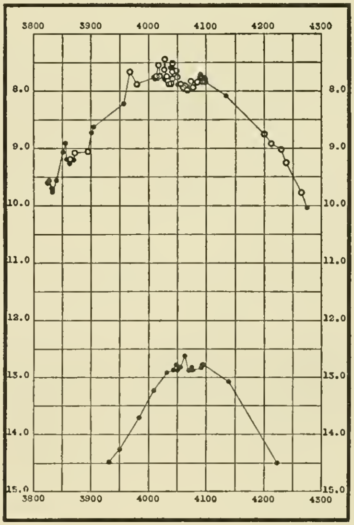

Fig. 1.

A curious result of the observations in 1897 is to show that the photographic and visual maxima were not simultaneous. The visual maximum apparently occurred about J.D. 14045 and the photographic maximum about J.D. 14080, more than a month later. The visual observations seem to indicate a secondary minimum about J.D. 14070, which is perhaps confirmed by the photographic observations for about the same date.

Color indices can be determined much more satisfactorily by comparisons of ordinary photographs with those taken on stained plates using color filters. This is especially true in the case of extremely red stars, for which the personal equation is liable to fluctuate in the case of visual observers. A comparison of plates taken with the 16-inch Metcalf Telescope, or the 4-inch Cooke Anastigmat which is attached to the same mounting, is convenient for this purpose. A preliminary determination of the color equation for ordinary plates taken with either instrument gives a value of about +0.8 magn., while for plates stained with erythrosine and exposed through a yellow screen it is about −0.2 magn. A comparison of the two kinds of plates, therefore, gives a color equation of about 1.0 magn., and color indices are probably nearly on the standard scale. On J.D. 19999, a yellow plate with the 16-inch was exposed simultaneously with the ordinary plate for which the magnitude of the variable, <12.8, is given in the third column of Table I. The observed photovisual magnitude was 7.66, and indicates a color index of more than five magnitudes. A yellow plate taken with the 16-inch on J.D. 20389 shows the variable as of the magnitude 9.36, while an ordinary plate taken two days later, as given on the last line of Table I, does not show the variable at all, although the images of sixteenth magnitude stars are seen. The resulting color index, depending on observations separated by two days, is at least six and a half magnitudes.

From this preliminary study, it is concluded that S Cephei has a color index of fully five magnitudes at maximum, that this increases as minimum is approached, and may become as great as six and a half magnitudes. The visual and photographic maxima are probably not simultaneous. Interesting results would probably be obtained from a similar study of other very red stars, whether variable, or not.

EDWARD C. PICKERING.

AUGUST 30, 1915.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 189.

ASTEROIDS BRIGHT IN 1916.

THE admirable pamphlets, extracted from the Berliner Astronomischen Jahrbuch are indispensable for the study of these objects. The extract giving the ephemerides for 1916 has just been received, issued as usual, on time. As copies of this work are not always accessible, a portion of the material has been reprinted in Table I. The objects selected are those which attain the magnitude 10.0, and brighter, and two others, Sirona (116) and Tercidina (345), which appear to be variable. The first five columns give the number of the asteroid, its name, the date of opposition, the magnitude at that time, and the magnitude at mean opposition. The sixth column is found by subtracting the fifth column from the fourth. Negative signs predominate and indicate that the asteroid is brighter than usual, and that conditions are therefore favorable for its observation. The next six columns give the date, the right ascension, and the declination, on the first, and on the last, date given in the Berlin ephemeris. The principal use of this table will be for observers who find a moving object on their photographs. The positions given will generally indicate whether the object is known. If bright, and not given in Table I, repeated photographs should be taken. A notification should be sent at once to this Observatory so that it may be confirmed and observed elsewhere.

Any moving object is likely to be of interest, if when near opposition its right ascension does not diminish daily by much more or less than a minute. An asteroid near the Pole of the Ecliptic, R.A. $=18^h\ 00^m$, Dec. $=+67°$, should be followed, since it may be very near the Earth, or its orbit may have a large inclination.

TABLE I.

ASTEROIDS BRIGHT IN 1916.

No.	Name.	Opp. 1916.	m	m_0	Diff.	Date.	R. A.	Dec.	Date.	R. A.	Dec.
							h. m.	° ′		h. m.	° ′
51	Nemausa	Feb. 7	9.5	9.8	−0.3	Jan. 29	9 27.7	+ 3 15	Mar. 9	8 57.2	+ 9 19
192	Nausikaa	" 12	10.0	9.3	+0.7	" 29	9 56.5	+17 19	" 9	9 16.9	+18 50
82	Alkmene	" 14	9.8	11.2	−1.4	" 29	10 1.0	+17 15	" 9	9 29.7	+19 2
39	Laetitia	Mar. 13	10.0	9.5	+0.5	Mar. 1	11 44.9	+ 5 14	Apr. 10	11 17.3	+ 9 50
41	Daphne	" 2	8.8	10.5	−1.7	" 17	12 54.1	− 2 4	" 26	12 34.5	+ 7 35
10	Hygiea	Apr. 9	8.9	9.5	−0.6	" 25	13 24.0	−15 3	May 4	12 55.9	−12 5
4	Vesta	" 15	6.2	6.5	−0.3	Apr. 2	13 47.9	+ 2 32	" 12	13 14.9	+ 4 29
7	Iris	" 18	9.6	8.4	+1.2	" 2	14 1.4	−19 15	" 12	13 26.5	−15 18
43	Ariadne	May 14	9.1	10.0	−0.9	May 4	15 35.3	−23 30	June 13	15 2.9	−19 34
3	Juno	" 19	10.0	8.7	+1.3	" 4	15 57.0	− 3 40	" 13	15 26.3	− 1 43
103	Hera	June 3	10.0	10.2	−0.2	" 20	16 58.9	−14 41	" 29	16 26.0	−14 30
29	Amphitrite	" 21	9.4	9.0	+0.4	June 13	18 7.5	−33 6	July 23	17 30.4	−32 13
116	Sirona	" 30	11.1	10.7	+0.4	" 21	18 47.0	−25 56	" 31	18 13.7	−26 40
21	Lutetia	July 7	9.3	10.1	−0.8	" 29	19 13.7	−24 39	Aug. 8	18 41.3	−26 20
345	Tercidina	" 11	11.6	11.2	+0.4	" 29	19 33.6	− 5 49	" 8	18 58.4	− 7 9
324	Bamberga	" 14	8.8	9.9	−1.1	" 29	19 50.8	−34 38	" 8	19 6.2	−32 38
185	Eunike	" 31	9.6	10.0	−0.4	July 23	20 51.3	− 0 28	Sept. 1	20 24.0	− 8 55
779	(1914 UB)	Aug. 14	10.0	11.5	−1.5	" 31	21 48.2	+ 3 52	" 9	21 13.6	+ 5 40
54	Alexandra	" 14	9.7	10.9	−1.2	" 31	21 49.4	−11 45	" 9	21 13.5	−10 5
349	Dembowska	" 22	9.4	9.8	−0.4	Aug. 8	22 19.6	−23 31	" 17	21 47.4	−24 45
30	Urania	" 29	9.4	9.9	−0.5	" 16	22 42.5	− 6 31	" 25	22 9.1	− 9 4
15	Eunomia	Sept. 2	7.7	8.6	−0.9	" 24	22 57.2	+10 0	Oct. 3	22 23.7	+ 8 50
11	Parthenope	" 5	8.7	9.3	−0.6	" 24	23 9.9	−10 21	" 3	22 41.3	−14 15
747	(1913 QZ)	" 7	9.6	11.0	−1.4	" 24	23 11.9	−20 13	" 3	22 47.6	−27 48
386	Siegena	" 7	9.6	10.5	−0.9	" 24	23 13.5	− 1 26	" 3	22 50.6	−10 17
219	Thusnelda	" 8	9.7	11.2	−1.5	" 24	23 16.3	+11 12	" 3	22 57.2	+ 2 29
511	Davida	" 29	9.2	9.6	−0.4	Sept. 17	0 31.6	−20 49	" 27	0 4.7	−23 17
84	Klio	Oct. 1	9.8	11.3	−1.5	" 17	0 46.3	+18 8	" 27	0 10.3	+17 42
13	Egeria	" 12	9.9	9.7	+0.2	Oct. 3	1 23.5	− 5 15	Nov. 12	0 46.2	− 4 8
22	Kalliope	" 13	9.4	9.8	−0.4	" 3	1 24.2	− 9 59	" 12	0 52.8	− 9 23
563	Suleika	Nov. 18	9.6	11.1	−1.5	Nov. 4	3 48.5	+ 8 32	Dec. 14	3 14.3	+11 22
372	Palma	" 19	9.1	10.5	−1.4	" 4	4 0.6	+58 55	" 14	3 12.0	+57 3
118	Peitho	" 20	9.8	10.8	−1.0	" 12	3 51.1	+22 13	" 22	3 14.8	+23 20
52	Europa	" 24	9.8	10.3	−0.5	" 12	4 11.6	+10 11	" 22	3 41.3	+ 9 50
23	Thalia	Dec. 3	9.4	10.5	−1.1	" 20	4 55.3	+22 35	" 30	4 14.7	+25 16
31	Euphrosyne	" 5	9.7	11.0	−1.3	" 20	5 7.4	+50 52	" 30	4 9.8	+54 28
20	Massalia	" 5	8.3	9.2	−0.9	" 20	5 2.0	+21 57	" 30	4 24.8	+20 38
9	Metis	" 7	8.1	8.9	−0.8	" 28	5 5.5	+23 31	" 38	4 28.9	+24 40
532	Herculina	" 17	9.7	9.8	−0.1	Dec. 6	5 51.5	+12 26	" 46	5 14.8	+15 51
69	Hesperia	" 18	9.4	10.7	−1.3	" 6	5 57.3	+10 7	" 46	5 26.6	+10 10
6	Hebe	" 23	8.0	8.5	−0.5	" 14	6 20.2	+ 3 19	" 54	5 45.6	+ 8 48

EDWARD C. PICKERING.

DECEMBER 29, 1915.

MAR 20 1916
UNIVERSITY OF TOR

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 190.

VARIABLE STARS OF SHORT PERIOD.

THREE papers on Variable Stars were presented by the writer to the American Academy of Arts and Sciences in the years 1880 and 1881. They are published in Volume 16 of the Proceedings, pages 1, 257, and 370. The second of these papers was reprinted in the Observatory 4, 225, 264, and 284. Some of the conclusions appear to have been overlooked, perhaps because they were insufficiently illustrated by diagrams. A classification of variables was proposed which is substantially that still adopted. The principal difference is that stars of the β Lyrae type were then placed with other stars of short period, while they are now generally classified with stars of the Algol type. It was shown that the light curves of four variables of short period could be represented by the formula, $L = a + m \sin (v + \alpha) + n \sin (2v + \beta)$, in which L is the actual intensity of the light derived from the magnitude, a, m, n, α, and β are arbitrary constants, and v is the angle corresponding to the time, if the period is taken equal to 360°. The formulae for the four stars are as follows: —

ζ Geminorum, $L = 89.6 + 10.2 \sin (v - 11^\circ.3)$
β Lyrae, $L = 81.1 + 4.1 \sin (v - 90^\circ) + 20.0 \sin (2v - 90^\circ)$
η Aquilae, $L = 74.6 + 20.0 \sin (v - 60^\circ) + 6.0 \sin (2v - 120^\circ)$
δ Cephei, $L = 72.1 + 20.0 \sin (v - 45^\circ) + 7.0 \sin (2v - 120^\circ)$

The constants were derived from a reduction of the mean of the light curves found by Argelander, Schönfeld, and Oudemans. Twenty-four points were determined on each light curve and the average deviations of the observed and computed values are ±0.5, ±2.8, ±1.8, and ±2.8, respectively. The unit is here one hundredth part of the maximum light and is about two hundredths of a magnitude. The light curves of β Lyrae, η Aquilae, and δ Cephei are shown in Figures 1, 2, and 3, respectively. The light curve of ζ Geminorum is not given since it is simply a sine curve. A glance at these figures shows that the observed values fall alternately above and below the computed values. It was shown in the second of the papers mentioned above on page 270 that these deviations could be represented by the terms 3 cos $3v$, 3 sin $(3v - 45°)$, and 4 sin $3v$. The average deviations were thus reduced to

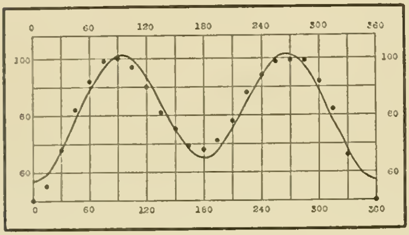

Fig. 1.

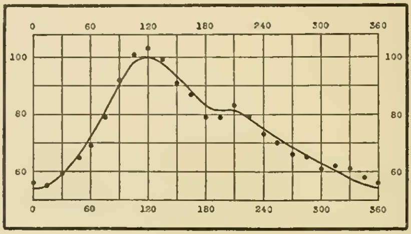

Fig. 2.

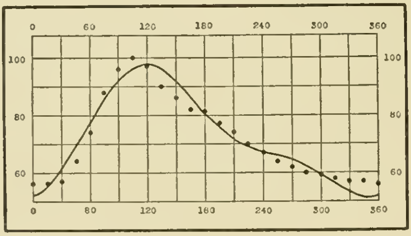

Fig. 3.

±1.6, ±1.1, and ±1.4, or nearly half their former value. It was stated that "No natural explanation can be offered for such terms, and the reduction might be thought accidental did it not occur in so many different curves." It was also shown that the terms sin $4v$ were not present.

Figures 4, 5, and 6, show the marked presence of the terms dependent on $3v$. Values of v are used as abscissas and the ordinates are taken from the third, seventh, and eleventh columns of the table on page 270. These ordinates are the sum of three residuals corresponding to the points in which v differs by 120°. Accordingly, they must be divided by three to find the average value of the correction.

A reasonable explanation was offered for the terms depending on v and $2v$, namely, that the first might be explained by unequal brightness of the different portions of the surface, and the second by an elongation, the body being an ellipsoid, rather than a sphere. No natural cause could be found for the term $3v$. Its reality is now rendered much more probable owing to the recent observations of the light curve of SU Draconis described in the Monthly Notices, 73, 166. Messrs. Martin and Plummer have shown that a term depending on $6v$ is there well indicated.

Mr. A. W. Roberts has shown that Algol stars may be arranged in an order such that their light curves will change progressively from that of β Persei to that of β Lyrae. It is therefore commonly assumed that the latter star is of the Algol type. But the spectroscope shows that several stars of the δ Cephei type are also spectroscopic binaries having their maximum brightness at the time of most rapid approach. Professor F. H. Loud offered the explanation that the increased brightness is due to the revolving body passing through a swarm of meteors which would thus render the front surface the brightest. Owing to the motion of the system with regard to the meteors, a new set of the latter would be encountered at each revolution. The term depending on $\sin v$ would thus be explained and also why the maximum brightness and velocity of approach always coincide. The term $2v$ would be explained if the bright body were elongated by the attraction of the central body.

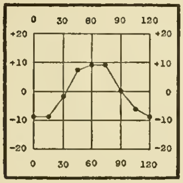

FIG. 4.

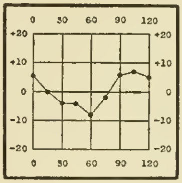

FIG. 5.

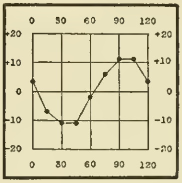

FIG. 6.

Since the light curves of stars of the β Lyrae and δ Cephei types can be represented by the same formula by changing the arbitrary constants, it seems natural to place them in the same class, and to regard their variation as due to the same cause. It is, therefore, not surprising to find that variations in light of stars of the δ Cephei type are due to revolution.

On the whole, it seems best to restore β Lyrae to a subdivision of stars of Class IV, regarding it as occupying an intermediate place between δ Cephei and β Persei.

It must be remembered that the most important of these conclusions were drawn thirty-five years ago from observations now more than half a century old. A vast amount of material of a high degree of accuracy has since been accumulated. The study of the light curves of Algol variables by Russell and Shapley has led to such important results, that a similar study of the variables of short period is much to be desired.

EDWARD C. PICKERING.

JANUARY 3, 1916.

MAR 20 1916
UNIVERSITY OF TOR

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 191.

---

19 NEW VARIABLE STARS NEAR THE SOUTH POLE.

Miss Henrietta S. Leavitt has prepared the following statement in continuation of the work of discovering variables from photographs covering the entire sky.

The region of the South Pole is shown on Harvard Map 55, described in H. C. 71 and 185 and also on the edge of Map 54. In the systematic examination of photographs taken with the 1-inch Cooke Anastigmat, for the purpose of discovering the probable number and distribution of variable stars, a plate having its centre at R. A. = $15^h.0$, Dec. = −90°, was substituted for the region of Map 55, which has its centre at R. A. = 0^h, Dec. = − 85°. A positive was made from this plate, and four negatives were successively superposed, as described in H. C. 127. All of them have centres at Dec. = −90°, and the right ascensions are $15^h.0$, $15^h.0$, $14^h.5$, and $18^h.0$, respectively. Stars north of −77° are not seen on these plates when at lower culmination, on account of the low altitude of the Pole at Arequipa. Five plates taken with the 8-inch Bache Telescope were also compared in the same way. The region south of Dec. −86° is common to them all.

The principal results are given in Table I, which is in the same form as Table I in H. C. 130, except that the first column gives the aperture of the instrument employed.

TABLE I.

NUMBER AND DISTRIBUTION OF THE VARIABLES.

Instr.	Region.	New Variables.	Total Found.	Proportion New	All.	Probable Number.	Proportion Found.	Probable No. Unknown.	Proportion Unknown.
1-inch	South Pole.	11	15	.73	24	49	.31	25	.51
8-inch	" "	8	10	.80	11	15	.67	4	.27

The number of variables in the region covered by the Cooke plates which were already known before the examination was begun, is 13. The number south of Dec. −86° which were already known at the time of beginning the examination of Bache plates is 3, namely R and S Octantis, and the new variable, *224187*, which had just been discovered on the Cooke plates. An analysis of the results shows that of all the variables brighter than the ninth magnitude at maximum, an eighth probably remain to be discovered south of Dec. −77°, and none south of Dec. −86°. Of those brighter than the eleventh magnitude, a third probably remain to be discovered south of Dec. −77°, and a sixth south of Dec. −86°. Of those brighter than the thirteenth magnitude and south of Dec. −86° the proportion not yet found is probably about a quarter. The number of stars on which these estimates of probability are based, however, is very small. The known variables re-discovered were *055686* R Octantis, *082476* R Chamaeleontis, *131283* U Octantis, *172586* S Octantis, and *205782* T Octantis, five in all.

TABLE II.

NEW VARIABLES NEAR THE SOUTH POLE.

Design.	H. V.	Constellation.	C. P. D.		R. A. 1900.			Dec. 1900.		Bright.	Faint.	Range.
					h.	m.	s.	°	′			
000486	3379	Octans	..	..	0	4	42	−86	43.6	10.2	<13	>2.8
042382	3380	Mensa	−82°	84	4	23	14	−82	6.4	9.9	10.9	1.0
100488	3381	Octans	..	..	10	4	25	−88	0.9	11.5	13.0	1.5
102983	3382	Octans	−83°	355	10	29	33	−83	50.2	8.6	11.0	2.4
115278	3383	Chamaeleon	..	..	11	52	24	−78	48.4	10.6	<13.0	>2.4
133283	3384	Octans	..	..	13	32	24	−83	53.5	9.8	10.6	0.8
133682	3385	Chamaeleon	..	..	13	36	16	−82	9.1	11.0	<13.5	>2.5
133988	3386	Octans	..	..	13	39	43	−88	7.8	11.2	12.3	1.1
165788	3387	Octans	..	..	16	57	19	−88	29.6	12.8	13.6	0.8
170174	3388	Apus	..	..	17	1	33	−74	1.3	10.0	10.6	0.6
170386	3389	Octans	..	..	17	3	47	−86	23.6	11.0	13.5	2.5
193278	3390	Octans	−79°	1040	19	32	50	−78	57.8	10.5	11.3	0.8
204475	3391	Octans	..	..	20	44	22	−75	21.0	10.0	<14.0	>4.0
210588	3392	Octans	..	..	21	5	10	−88	4.8	11.2	13.4	2.2
212477	3393	Octans	..	..	21	24	55	−77	44.6	10.2	11.1	0.9
213687	3394	Octans	..	..	21	36	43	−87	20.0	12.0	13.0	1.0
213883	3395	Octans	..	..	21	38	22	−83	14.2	10.5	11.3	0.8
224187	3396	Octans	..	..	22	41	24	−87	34.5	10.5	<14	>3.5
235388	3397	Octans	..	..	23	53	45	−88	25.7	13.5	14.3	0.8

The new variables are given in Table II, in the same form as Table II in H. C. 130. Variables *042382*, *102983*, *133682*, *133988*, and *210588*, probably have long periods.

REMARKS.

100488. This variable probably has a very brief maximum, as it appears faint on the majority of plates.

170174. This variable is apparently of the Algol type.

213883. Period evidently short. Maximum probably very brief.

235388. The maximum is probably very brief, as the variable is faint on 18 out of 20 plates examined. On account of its faintness, the number of plates on which it can be observed is not large, and it is not yet known whether the period is short.

EDWARD C. PICKERING.

FEBRUARY 19, 1916.

[illegible]

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 192.

POTSDAM AND HARVARD PHOTOMETRIC MAGNITUDES.

Figure 1 of H. C. 191 is a good example of the value of the graphical method. A term in the light curves of three variables of short period, dependent on one third of the period, was pointed out more than thirty years ago. Although hitherto ignored, its reality is rendered unmistakable by the figure in the particular light curves discussed. A similar case occurs in H.A. 64, 126. The agreement of the Potsdam and Harvard magnitudes is so good, when corrected for the marked difference in color equation, that the systematic error remaining, although mentioned, was considered too small for further discussion. These outstanding residuals whose average value is ±0.024 magn., or a fortieth of a magnitude, are plotted in Fig. 1. For each of the six classes of spectra, points are plotted in which abscissas are magnitudes of the stars on a scale of 1 magn. =4 mm., and ordinates are residuals taken from the last portion of Table XII on page 126, on the large scale of 1 magn. =100 mm. The systematic error is obvious, the residuals increasing for faint stars of Classes B and A, and diminishing for Classes K and M. In Table I, the first seven columns are taken from Table XII. The first column gives the mean magnitudes of the groups, and the next six give the mean residuals corresponding to the six classes of spectra. These residuals remain after applying first, a correction for color equation and secondly, subtracting the mean for each magnitude. The next six columns give a proposed correction. Starting with *4*, the first number in the first column, the successive numbers in this column, and the successive first numbers of each column are increased by 2. The first number in the second column, and the second number in the first column are successively increased by 1. The third column and third line are thus all 0, and the last column and last line are diminished in each case by 3. Applying these numbers as a correction by subtracting them from the numbers in the six preceding columns

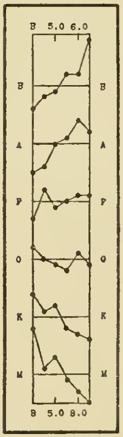

FIG. 1.

we have the residuals in the last six columns. A geometrical conception of this correction will be furnished, if we regard it as a hyperbolic paraboloid in which the directrices are inclined in opposite directions at angles of 45°, and the generatrix is always horizontal.

TABLE I.

CORRECTED RESIDUALS.

Magn.	After 2d Correction.						3d Correction.						After 3d Correction.					
	B	A	F	G	K	M	B	A	F	G	K	M	B	A	F	G	K	M
B	*4*	*5*	*3*	2	4	8	*4*	*2*	0	2	4	6	0	*3*	*3*	0	0	2
4.5	*2*	*4*	2	0	1	1	*2*	*1*	0	1	2	3	0	*3*	2	*1*	*1*	*2*
5.0	*1*	0	*1*	*1*	2	3	0	0	0	0	0	0	*1*	0	*1*	*1*	2	3
5.5	2	1	0	*2*	*2*	*1*	2	1	0	*1*	*2*	*3*	0	0	0	*1*	0	2
6.0	2	4	1	1	*3*	*3*	4	2	0	*2*	*4*	*6*	*2*	2	1	3	1	3
6.5	8	2	1	*1*	*4*	*5*	6	3	0	*3*	*6*	*9*	2	*1*	1	2	2	4

The average value of the residuals by applying the third correction is reduced from ±0.024 magn. to ±0.014 magn. Even here a small systematic error remains. The nine left-hand upper residuals have a mean value of −0.01, and the right-hand lower, a mean value of +0.02. The last column depends on stars of Class M, which are comparatively few in number, and very red. These residuals are large. Omitting them, the mean value is ±0.012. To eliminate these errors it would be necessary to carry the results to thousandths of a magnitude. The residuals must be multiplied by 0.845 to convert them into probable errors. It may, therefore, fairly be said that the accidental errors of the Potsdam and Harvard measures are so small that the differences in these thirty-six groups do not greatly exceed a hundredth of a magnitude.

EDWARD C. PICKERING,
Director.

Cambridge, Mass., U. S. A.
June 11, 1916.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 193.

CLUSTER VARIABLES WITH DOUBLE MAXIMA.

The Cluster Variables in ω Centauri were divided in H.A. 38, 132, for convenience of reference, into three groups, a, b, and c, which were placed under Class IV of Professor Pickering's classification. The stars of sub-class a have light curves of the ordinary cluster type, with extremely rapid rise to maximum, and periods of about half a day; those of sub-class b, less range of variation in brightness, less rapid changes, and periods of about two-thirds of a day; those of sub-class c, light curves resembling a sine curve, and periods of about one-third of a day. In H.A. 78, Part 1, all the variables in Messier 3, so far as they were determined, appeared to belong to sub-class a. The variables in Messier 5, a discussion of which is now in process of publication in H.A. 78, Part 2, are in general of the same cluster type. Eight stars have been found in this cluster, however, whose light curves present peculiarities not hitherto recognized. No periods were found for these stars at first, since no period of the usual length of about half a day would satisfy the observations. It appeared later, however, that periods of about a fourth of a day gave accordant results. The mean period of 61 stars in Messier 5 of the ordinary cluster type is $0^d.547$, varying between $0^d.449632$ and $0^d.845110$, while the mean period between successive maxima of the 8 stars in question is $0^d.271$, varying between $0^d.230968$ and $0^d.358385$. Of the former, however, only 2 have periods greater than $0^d.70$, and of the latter only 2, greater than $0^d.28$. Since the mean period of the 8 stars is one-half that of the 61 ordinary variables, the conclusion appears obvious that some intimate relation must exist between them. Perhaps the most simple explanation is that such a star, having an apparent period of one-half the usual length, is a double variable formed of two components, each of the ordinary cluster type and with alternating maxima. The real period of each component in this case would be twice the apparent period, and, since these conditions are permanent, the pair must form not only an optical, but a physical double. The form of the light curve of these 8 stars, which is distinctly different from that of the other variables, lends support to this hypothesis. It is similar to that of ζ Geminorum and to those of sub-class c in ω Centauri, that is, to a sine curve. It can readily be resolved into two light curves of the usual cluster type.

Variable No. 62, in Messier 5, is a good example of such a star. Twice the simple period is $0^d.562815$, and an apparent, secular oscillation in the length of the period is well represented by the term $+0^d.055 \sin (0°.0158\, E + 214°.4)$. For this star a special sequence of comparison stars was selected and remeasures of the variable were made with great care by Miss I. E. Woods and the writer. The resulting light curve for 24 equal parts is given in the first and second columns of Table I, and agrees closely with that derived independently from the earlier measures. A resolution of this curve has been made into two curves, A and B, whose combined light, expressed in magnitudes, at each phase equals that of No. 62. These are given in the third and fourth columns of the table. Since both these curves are of the cluster type, such an origin for this star seems not improbable. The precise form of A and B can be changed, as any number of resolutions is possible.

TABLE I.

Part.	Var. 62.	A.	B.	Part.	Var. 62.	A.	B.
0	14.65	15.03	15.97	12	14.65	16.45	14.88
1	14.68	15.05	16.02	13	14.67	16.52	14.89
2	14.76	15.16	16.04	14	14.81	16.58	15.05
3	14.86	15.29	16.08	15	14.96	16.63	15.22
4	15.01	15.50	16.10	16	15.13	16.65	15.43
5	15.15	15.72	16.12	17	15.25	16.70	15.58
6	15.27	15.90	16.15	18	15.30	16.70	15.65
7	15.35	16.03	16.17	19	15.28	16.45	15.73
8	15.36	16.10	16.12	20	15.21	16.16	15.80
9	15.24	16.21	15.82	21	15.07	15.85	15.79
10	14.94	16.30	15.30	22	14.86	15.40	15.90
11	14.70	16.37	14.96	23	14.71	15.14	15.93

After these stars had been found in Messier 5, a re-examination was made of some of the results given in H.A. 38 and 78, Part 1, for ω Centauri and Messier 3. In the latter case, the light curves show great similarity. One probable case of a double variable was found, however, No. 37, for which no period was determined when the discussion of the cluster was made. A period of about one-third of a day, $0^d.326350$, was found to satisfy the observations fairly well. This period is somewhat greater than one-half the mean period, $0^d.541$, of the variables in Messier 3, but 19 variables in the cluster have periods between $0^d.60$ and $0^d.71$, or about twice that of No. 37. It seems significant, also, that in ω Centauri the mean length of the periods of the variables of sub-class c is $0^d.395$, which is about half that, $0^d.752$, of group b.

These results will be given in greater detail in H.A. 78, Part 2. They are referred to in this circular in the hope that similar variables may be found among the brighter stars outside the globular clusters, as has been true of variables of the ordinary cluster type. Aside from the form of the light curve, it seems possible to test the above hypothesis from spectroscopic considerations. Kiess has shown for the variable of cluster type, RR Lyrae, that the displacement of the spectral lines occurs, which is commonly referred to elliptical motion in a binary system; and Shapley has announced for the same star that an orderly sequence in the type of spectrum takes place during the period of light changes. The spectrum itself and the sequence of changes in displacement and type would be affected, theoretically at least, by duplicity.

The striking uniformity of period of cluster variables must have some physical cause, which may separate them somewhat from other variables of short period. The mean period in ω Centauri is $0^d.549$; in Messier 3, $0^d.541$; and in Messier 5, $0^d.547$. Similar results have been found in other clusters, the discussion of which is incomplete.

These periods appear in many cases to be perfectly uniform, even when the observations, 100 or more in number, extend over more than 10,000 returns of maximum. In other cases, however, a secular variation in the length of the period is apparent, which can often be fairly well expressed by a single sine term.

Our results give no conclusive proof of irregularities in the form of the light curve at different epochs. Residuals from the mean curve are often large, sometimes unaccountably so, but we have preferred to attribute these provisionally to errors of one kind, or another. Differences of opinion in regard to these irregularities are found among experts, even in the case of brighter and carefully studied stars, as, for example, XX Cygni. The matter can hardly be considered as definitely proved until such irregularities are verified by the independent observations of different observers, using different methods, at the same epochs.

As to whether these stars are spectroscopic binaries must still be regarded as an open question. The introduction of the above hypothesis, to account for the stars of double maxima, still further complicates the problem, since, if an ordinary cluster variable is a binary, the double variable must be a system of at least four components; and if we ascribe the secular variation of the period, which is sometimes apparent, to the action of another body, the system becomes still more complex.

The term "Antalgol," applied to cluster variables in general, is evidently a misnomer. The light curve of the cluster type is by no means an inverted Algol curve.

S. I. BAILEY.

SEPTEMBER 1, 1916.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 194.

TWO NEW VARIABLE STARS. H. V. 3398 AND 3399.

DURING an examination of Harvard photographs taken with a 1-inch Cooke lens, the star +60° 1691 was found to be a variable. This is the double star, Number 7729 (Σ 2092) in Burnham's Catalogue of Double Stars, position angle, 5°.9, distance, 8″.04. It has the appearance of a single star on plates taken with the 1-inch Cooke Telescope, but the two components are separated on plates taken with the 16-inch Metcalf Telescope. Measures of the combined light of the two stars were made on 254 plates, which were taken with the former instrument. These give 8.5 as the magnitude at maximum, which is the normal brightness, and 9.1, the magnitude at minimum. The approximate period is $3^d.501$. The magnitudes of the two stars on plates taken with the 16-inch Telescope are as follows: —

Plate No.	J.D.	N.	S.
MC 3338	2419890.777	10.2	10.7
MC 3368	2419895.771	10.2	9.8

N signifies the northern and S, the southern component. The magnitudes of the comparison stars used for both series of plates were obtained on the international scale. The time of exposure of Plate MC 3338 coincides with the predicted time of minimum, if we use the period, $3^d.501$, which was found from measures of the combined light. It appears, therefore, that the southern component of the double star is a variable of short period, probably of the Algol type, and has a range of at least nine-tenths of a magnitude. The position of this double star for 1900 is, R. A. $16^h\ 37^m\ 41^s$, Dec. +60° 54′.4.

The star whose position for 1900 is R. A. $2^h\ 26^m\ 19^s$, Dec. +35° 7′.8 is also a variable. It is 2′ south of +34° 455, which it precedes by 3^s. By direct comparison with stars of which the magnitudes were derived on the international scale, this variable has been measured on 50 Harvard photographs, of which 48 were taken with the 8-inch Draper Telescope between the

years 1890 and 1907, and 2 with the 16-inch Metcalf Telescope, during the year 1914. The magnitude is 12.9 at minimum brightness, and 11.9, or brighter, at maximum. The variable is faint on the majority of the plates, being bright on only five. It has probably a short period, possibly of seven days, or less.

MARGARET HARWOOD,
Director Maria Mitchell Observatory.

SEPTEMBER 2, 1916.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 195.

PROBABLE ERROR.

Probable error is defined in Chauvenet's Astronomy, page 488, as "the error which occupies the middle place in the series of errors arranged in the order of their magnitude, so that the number of errors which are less than this assumed error is the same as the number of errors which exceed it." It will often be easier to arrange the errors, or residuals, of a series of measures than to determine the probable error by the usual formula. It is impossible to determine a probable error with accuracy. At best it can only be regarded as a convenient method of determining the approximate precision, and one by which all computers will arrive at the same conclusion. The method to be here proposed has one great advantage over the usual method. In almost all physical measurements errors appear which are much larger than would be expected from the probability curve. The question is whether the corresponding values should be rejected. Five times the average deviation is a convenient criterion for rejection. But should this deviation be computed before or after the observation is rejected? The residuals after rejecting an observation may be very different from those first obtained. The probability of two or more erroneous observations is much less than for one, and the rule in this case should be changed. The difficulties are greatly diminished if the probable error is derived from the order of the residuals. If the number of observations is odd it is only necessary to group the residuals and select the one for which the number greater is equal to the number less and it will equal the probable error. If the number is even the probable error will lie between the two middle residuals and may be taken equal to their mean.

If several of the residuals have the same value as the intermediate residuals, the problem becomes more complicated. Let n be the number of these residuals, and a and b the limits between which these residuals must lie. We may assume that they are distributed uniformly between these limits. Then their values may be assumed to be $a+(b-a)/2n$, $a+3\,(b-a)/2n$, $a+5\,(b-a)/2n$, etc. If the total number of residuals is odd, and m of the residuals have the same value as the middle residual, and are less than it, the value of the latter will be $a+(2\,m+1)$

$(b - a)/2n$ and this will be the probable error. If the total number is even, and m of the residuals are assumed to be less than the two middle residuals, the probable error will be $a + (m + 1)\ (b - a)/n$. Thus, suppose we have five residuals whose value is 7. They may have any value from 6.5 to 7.5. Then, $a = 6.5$, $b = 7.5$, $n = 5$, and the residuals become 6.6, 6.8, 7.0, 7.2, and 7.4. If the total number of residuals is odd and the fourth of these is the middle residual, we have $m = 3$, and the probable error is $6.5 + 7 \times 1.0/10 = 7.2$. If the third and fourth residuals are the middle ones, then $m = 2$, and the probable error is $6.5 + 3 \times 1.0/5 = 7.1$.

TABLE I.

Prop.	Coeff.
.50	2.078
.55	1.873
.60	1.701
.65	1.553
.70	1.424
.75	1.310
.80	1.207
.85	1.114
.90	1.026
.95	0.941
1.00	0.845

A more satisfactory method of determining the probable error is that of Peters, multiplying the arithmetical mean of the residuals by 0.845. It is here assumed that the number of observations is very large. When the large residuals are unduly numerous this formula is to be preferred to that of Gauss, depending on the square of the residuals, since the latter formula gives undue weight to large residuals. The result found by either formula will be greatly altered if we reject one or more large residuals. We may, however, apply Peters' formula to a portion only of the residuals by changing the coefficient, 0.845. Professor King has computed Table I which gives for various proportions of the residuals the corresponding coefficient, if the residuals selected are those which have the smallest numerical values. Thus, if we select half of the smallest residuals, take their mean, and multiply by 2.078, we shall obtain the probable error. If the residuals follow the law of probabilities, the result will be the same as if we multiply the mean of all by 0.845. But if one, or more, of the residuals are large and we are in doubt whether they should be rejected, this step would greatly affect the latter method, while the effect would be very slight in the method here proposed. If we prefer to use nine-tenths of the residuals we must multiply their average value by 1.026. If we retain 0.52 of the residuals, their average value will be twice the probable error, and if we retain 0.92, the average deviation will equal the probable error. A convenient rule will be to omit one-twelfth of the observations, selecting those which are most discordant, and the average value of the remaining residuals will equal the probable error.

EDWARD C. PICKERING.

September 5, 1916.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 196.

STARS HAVING PECULIAR SPECTRA. 13 NEW VARIABLE STARS.

LISTS of stars having peculiar spectra, found during observations for the New Draper Catalogue have already been published in Circulars 178 and 184. Table I contains an additional list of variables and spectra having bright lines or other peculiarities. The successive columns give the Durchmusterung number, the right ascension for 1900, the declination for 1900, the photometric magnitude, or the Durchmusterung magnitude reduced to the photometric scale and carried to tenths only, the class of spectrum, and a brief description of the observed peculiarities. The variability of the stars announced in this Table has been confirmed by Miss J. C. Mackie. The scale of magnitudes given is only approximate, and is based on adjacent Durchmusterung stars, except in the case of the two variables, 201276, and 205204, for which the International scale of magnitudes is used.

TABLE I.

STARS HAVING PECULIAR SPECTRA. 13 NEW VARIABLE STARS.

DM.	R.A. 1900.		Dec. 1900.		Magn.	Sp.	Remarks.
	h.	m.	°	′			
+56° 565	2	14.7	+56	56	9.4	Bp	Hβ bright.
+56° 635	2	22.9	+56	48	8.5	B3p	Hβ bright.
+56° 642	2	24.2	+56	27	8.7	B0p	Hβ bright.
....	3	29.6	−16	30	..	Md	RT Eridani. H.V. 3039. Hδ bright.
+45° 904	4	10.1	+45	58	8.6	Bp	Hβ bright.
−10° 993	4	39.0	−10	53	8.1	A5	Variable of the Algol type. H.V. 3400.
....	10	30.5	−53	44	..	N	Variable. H.V. 3401.
....	13	12.3	−83	42	..	Md	U Octantis.
−59° 5228	13	44.4	−59	55	9.6	Md	UX Centauri. H.V. 1304. Hδ bright.
−37° 10602	15	50.1	−37	32	10.2	Pec.	Bright lines. Variable. H.V. 3402.
−21° 4270	16	0.1	−21	28	9.8	Md	Z Scorpii. Hγ and Hδ are bright.
− 9° 4329	16	7.8	−10	5	10.0	Mc	Variable. H.V. 3403.
−44° 10723	16	8.3	−44	32	11.6	Md	Hγ and Hδ bright. Variable H.V. 3404.
R	16	28.2	−68	20	..	Md	Hγ and Hδ bright. Variable. H.V. 3405.
−46° 11019	16	39.2	−46	55	7.7	Oe	Bright lines at 4633 and 4688.
....	17	17.2	−38	47	..	Md	Hγ and Hδ bright. Variable. H.V. 3406.
....	17	40.3	−52	37	..	Md	Hγ and Hδ bright. Variable. H.V. 3407.
−36° 12072	17	52.7	−36	0	7.26	Oe	Bright band 4688 present.
−44° 12598	18	19.1	−44	20	11.6	Md	Hγ and Hδ bright. Variable. H.V. 3408.
....	18	19.3	−50	54	..	Md	Hγ and Hδ bright. Variable. H.V. 3409.
− 5° 4760	18	42.2	− 5	49	var.	R	R Scuti. Spectrum Variable.

DM.	R.A. 1900.		Dec. 1900.		Magn.	Sp.	Remarks.
	h.	m.	°	′			
−32° 14673	18	49.1	−32	23	11.0	N	
−55° 8995	19	0.0	−55	43	10.0	R	
−36° 13638	19	31.9	−36	37	9.9	Md	Hγ and Hδ bright. Variable. H.V. 3410.
− 0° 3883	19	52.5	− 0	2	9.8	N	
+76° 784	20	12.9	+76	52	9.0	Md	Hβ and Hγ bright. Variable. H.V. 3411.
+ 4° 4584	20	52.2	+ 4	42	8.2	A0	Variable of the Algol type. H.V. 3412.
+61° 2112	21	16.7	+61	25	6.64	B0p	Hβ bright.
....	22	49.5	− 7	30	..	R	
....	23	6.2	+45	46	..	R	

REMARKS.

043910. —Eridani. This star is faint on 7 out of 210 photographs examined. These minima are satisfied by the formula J.D. 2413013 + $19^{d}.64n$. The range of variation is from magn. 8.3 to 9.5.

103053. —Velorum. The variability was confirmed by an examination of 10 photographs taken between June 11, 1898 and April 5, 1912. The star was near maximum on June 11, 1898, April 2, 1904, March 28, 1908, and April 24, 1909. The period may be about one year. The variation is from magn. 11 to <15.

155037. — Lupi. The spectrum of this star is very peculiar. Hβ, Hγ, and Hδ are bright, also the bands H and K. The underlying spectrum does not appear to be Class M. The variability was confirmed on 12 photographs taken between June 23, 1893 and July 20, 1912. The range is from magn. 9.0 to 11. The period may be irregular.

160710. — Scorpii. The variability was confirmed on 33 photographs taken with the 8-inch Draper and 1-inch Cooke telescopes, between July 10, 1896 and June 17, 1912. The range is from magn. 10 to 11. The variation is well shown on both chart and spectrum plates.

160844. — Normae. The variability was confirmed on 28 photographs taken between May 28, 1891 and April 20, 1911. The period appears to be about one year and the range of variation to be from magn. 9.9 to <13.

162868. — Trianguli Australis. This star is 4^{s} following and $0'.6$ south of C.P.D. −68° 2769. The range of variation is from magn. 9.8 to <13. At maximum, its brightness is equal to that of the adjacent star. Maxima occurred near the dates, July 2, 1900 and July 22, 1908.

171738. — Scorpii. The variability was confirmed by an examination of 10 photographs, taken between March 28, 1898 and May 11, 1911. They show that the star was near maximum on July 15, 1899 and May 19, 1908. On July 11, 1902, it was invisible on a good photograph taken with the 8-inch Bache Telescope and having an exposure of 60^{m}. The range is from magnitude 11.6 to <15.

174052. — Arae. The variability was confirmed by an examination of 10 photographs taken between June 14, 1894 and June 26, 1909. The range is from magn. 11 to <14.

181944. — Coronae Austrinae. The variability was confirmed by an examination of 10 photographs taken between May 29, 1891, and May 30, 1909. The range is from magn. 10.5, approximately, to <15. The star was near maximum on May 29, 1891, October 15, 1896, July 21, 1908, and May 30, 1909. On June 11, 1901 it was invisible on a good photograph taken with the 8-inch Bache Telescope and having an exposure of 60^{m}.

181950. — Telescopii. The variability was confirmed on 11 photographs taken with the 8-inch Bache Telescope between July 20, 1894 and March 30, 1912. The range is from magn. 11 to <15.

184205. R Scuti. The spectrum of this irregular variable star changes. At maximum it is Class G5, at minimum the spectrum is banded, Class Ma. Several photographs of these different spectra have been obtained, and also intermediate phases of spectra such as K0, K2, corresponding to intermediate phases in the light of the star.

193136. — Sagittarii. The variability was confirmed by an examination of 10 photographs, taken between April 28, 1893 and June 9, 1909. The range is from magn. 10.5 to <13.

201276. — Cephei. The variability was confirmed by an examination of 10 photographs taken with the 16-inch Metcalf Telescope. The star was near maximum in October 1913, September 1914, and was invisible, on March 7, 1913, July 3, 1914 and June 25, 1915. The range is from magn. 11.0 to <14.

205204. — Equulei. This variable is of the Algol type, and was found by an inspection of a photograph taken with the 1-inch Cooke Telescope, on July 8, 1905, and having 13 successive exposures of each star. A minimum occurred during that night. Observations of the light on 730 photographs have been made by Miss M. E. O'Reilly. A preliminary study of these observations gives the following elements for minima, J.D. 2410002.337 + $3^{d}.436n$. The range of variation is from magn. 8.4 to 10.3.

Table II gives a continuation of the list of stars having composite spectra. The first four columns contain the Durchmusterung number, the right ascension fo 1900, the declination for 1900, and the photometric or reduced Durchmusterung magnitude, the latter being carried to tenths only. The fifth column gives the number in Burnham's "General Catalogue of Double Stars" or the hour and number in Innes' "Southern Double Stars," for stars contained in those works. The sixth and seventh columns give the class of spectrum of the brighter and fainter components. In 10 of these cases a known companion, either visual or spectroscopic, accounts for the observed peculiarities. The others are new double stars.

TABLE II.

STARS HAVING COMPOSITE SPECTRA. 51 NEW DOUBLE STARS.

DM.	R.A. 1900.	Dec. 1900.	Magn.	Bu.	Brighter.	Fainter.
	h. m.	° ′				
+63° 99	0 44.7	+63 42	5.45	....	F2	A2
+65° 239	2 6.6	+66 3	6.15	....	F5	A2
− 3° 340	2 8.7	− 3 30	7.34	....	A2	G0
+48° 765	2 43.1	+48 24	7.8	R	A2	G
+48° 780	2 45.5	+48 13	8.6	....	G0	A
+31° 526	2 55.4	+32 1	6.71	1530	G5	A5
−21° 953	4 38.2	−21 10	7.63	....	F5	A3
−11° 1951	7 23.2	−11 21	5.86	4080	F5	A0
−14° 1971	7 29.2	−14 18	5.06	....	K5	B
−60° 3955	12 19.3	−60 21	7.11	....	G0	A2
−41° 7236	12 26.1	−41 48	10.6	....	G0	A
−61° 3906	13 34.6	−61 22	9.0	....	G0	A3
−61° 4041	13 42.3	−61 36	7.9	13h 73	G5	F5
−66° 2348	13 43.6	−66 20	9.2	....	Ma	A
−63° 3920	13 59.7	−62 58	8.0	....	G0	A3
−12° 3958	14 0.6	−12 36	7.9	6718	F2	A3
−55° 5882	14 0.8	−55 52	8.7	....	G5	A5
−53° 5912	14 6.6	−53 12	5.48	....	K0	A2
−56° 6251	14 14.5	−56 11	8.9	....	A	G
−58° 5719	14 41.7	−58 59	6.52	....	G5	A3
−16° 4095	15 24.0	−16 30	8.8	....	F5	A2
−58° 6139	15 32.2	−58 49	8.9	....	K0	A2
−57° 7155	15 35.0	−57 48	8.5	15h 72	Mb	A3
−58° 6252	15 37.1	−58 22	8.4	....	F8	A5
−41° 10425	15 48.6	−41 38	8.7	....	F5	A3
−53° 6882	15 50.9	−53 47	8.6	....	F2	A2
+37° 2708	15 59.6	+36 55	5.85	....	F5	A2
−56° 7333	16 1.1	−56 38	8.4	....	G5	A5
−60° 6465	16 6.3	−61 1	8.6	....	F5	A3
−53° 7838	16 14.0	−53 33	9.6	....	K0	A3

DM.	R.A. 1900.		Dec. 1900.		Magn.	Bu.	Brighter.	Fainter.
	h.	m.	°	'				
−53° 7930	16	16.9	−53	21	8.0	....	G0	A5
−34° 11732	17	23.9	−34	27	7.8	....	F5	A5
−50° 11346	17	24.4	−50	59	8.5	....	Mb	A2
−39° 12027	17	49.8	−39	55	7.34	17^h 109	F5	A2
− 1° 3421	17	51.1	− 1	27	9.8	....	F5	A2
−20° 4945	17	55.1	−20	48	8.4	8275	F8	A2
−35° 12274	18	1.0	−35	24	8.9	....	F5	A3
−30° 15290	18	2.5	−30	0	7.00	....	G5	A2
−28° 14282	18	6.3	−28	16	7.37	....	F5	A
−10° 4651	18	14.1	−10	58	8.6	....	G5	A5
+ 7° 3682	18	20.8	+ 7	59	5.69	....	G0	A3
+61° 1771	18	43.4	+61	51	8.0	....	F5	A2
+22° 3524	18	50.5	+22	32	4.56	R	G5	A3
+37° 3357	19	6.3	+37	38	6.76	....	F0	A3
− 7° 4929	19	15.2	− 6	56	8.7	....	K0	A2
+ 0° 4182	19	16.5	+ 0	15	7.53	....	F5	A5
+24° 3914	19	47.8	+24	44	5.67	....	F5	A2
−79° 1049	19	48.5	−79	6	7.9	....	F8	A3
+47° 3059	20	12.3	+47	24	4.16	R	K0	A3
+29° 3989	20	15.0	+29	11	7.20	....	F5	A0
+23° 4004	20	20.1	+23	58	6.96	....	G0	A3
+48° 3128	20	24.0	+49	3	5.72	....	F0	A0
+23° 4085	20	34.3	+23	19	6.13	....	K0	A3
+14° 4478	20	51.7	+14	27	7.53	....	K0	A2
+15° 4320	20	58.3	+15	23	7.69	....	G5	A5
+45° 3410	21	3.3	+45	17	7.32	....	G0	A0
+58° 2249	21	16.5	+58	13	5.79	10925	K0	A0
−43° 14835	21	54.4	−42	56	7.3	....	F8	A3
+44° 4114	22	18.3	+44	56	8.2	....	F0	A2
+65° 1759	22	18.8	+66	12	6.74	....	F5	A2
+80° 731	22	39.2	+80	52	6.90	....	F8	A5

REMARKS.

h. m.

2 8.7. The two components are probably of nearly equal photographic magnitude.

2 43.1. This is Burnham 1437, but the fainter component is magnitude 12.0, and is probably too faint to be seen on this photograph. It therefore appears that there is still another component of nearly the same brightness as the primary star.

13 59.7. The two components appear to be of nearly equal photographic magnitude.

14 14.5. The two components appear to be of nearly equal photographic magnitude.

h. m.

18 50.5 This is 113 Herculis, Burnham 8908. The visual companions, magnitudes 12.5 and 12.5, are probably too faint to affect the observed spectrum. As this star is a spectroscopic binary, the spectra are probably due to the two components.

20 12.3. This is o^2 Cygni, Burnham 10060. The spectrum of the visual companion is separated from that of the brighter star. As this star is a known spectroscopic binary, the spectra are probably due to the two components.

21 3.3. The two components appear to be of nearly equal photographic magnitude.

ANNIE J. CANNON.

September 23, 1916.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 197.

MAXIMA IN 1917 OF VARIABLES OF LONG PERIOD.

VARIABLE stars of long period are somewhat irregular in their changes, so that it is difficult to predict the times of maximum light. An extensive compilation of the magnitudes of these variables is in progress by Mr. Leon Campbell, who has determined the dates contained in Table I. The most accurate method of predicting the maxima in 1917 appears to be, to determine the approximate dates of recent maxima by inspection of the light curves, from material collected here, and adding the best known value of the period. The designation of the star in hours and minutes of right ascension and degrees of declination is given in the first column of Table I. The designation of the star according to the notation of Argelander is given in the second column. The date of the predicted maximum is given in the third column.

TABLE I.

PREDICTED MAXIMA.

Desig.	Name.	Date.	Desig.	Name.	Date.	Desig.	Name.	Date.
		1917.			1917.			1917.
001046	X Androm.	Mar. 28	010940	U Androm.	Nov. 13	015912	S Arietis	Jan. 1
001726	T "	May 2	011041	UZ "	Feb. 10	"	" "	Oct. 18
001755	T Cassiop.	June 8	"	" "	Dec. 17	021024	R "	Apr. 3
001838	R Androm.	Aug. 24	011208	S Piscium	Feb. 23	"	" "	Oct. 8
001909	S Ceti	July 29	011272	S Cassiop.	No Max.	021143a	W Androm.	Apr. 17
003179	Y Cephei	Oct. 20	011712	U Piscium	Jan. 25	021281	Z Cephei	Sept. 26
004047	U Cassiop.	May 16	"	" "	July 26	*021403*	o Ceti	Oct. 15
004132	RW Androm.	Nov. 30	012350	RZ Persei	May 6	*022000*	R "	May 29
004435	V "	May 16	012502	R Piscium	Oct. 12	"	" "	Nov. 12
004533	RR "	Aug. 19	013238	RU Androm.	Mar. 6	022150	RR Persei	Oct. 8
004746	RV Cassiop.	June 28	013338	Y "	Jan. 5	*022813*	U Ceti	Feb. 2
004958	W "	July 15	"	" "	Aug. 15	"	" "	Sept. 26
010102	Z Ceti	Mar. 24	014958	X Cassiop.	June 28	022980	RR Cephei	Mar. 24
"	" "	Sept. 26	015354	U Persei	Oct. 24	023133	R Trianguli	Mar. 9

Desig.	Name.	Date.	Desig.	Name.	Date.	Desig.	Name.	Date.
		1917.			1917.			1917.
023133	R Trianguli	Dec. 1	065355	R Lyncis	Mar. 12	123160	T Urs. Maj.	Nov. 1
030514	U Arietis	Mar. 22	070109	V Can. Min.	Oct. 20	123307	R Virginis	Mar. 27
031401	X Ceti	Apr. 26	070122a	R Gemin.	Oct. 24	"	" "	Aug. 19
"	" "	Oct. 18	070310	R Can. Min.	June 12	123459	RS Urs. Maj.	June 5
032043	Y Persei	Mar. 1	071201	RR Monoc.	Apr. 21	123961	S " "	Apr. 16
"	" "	Nov. 13	071713	V Gemin.	Feb. 26	"	" " "	Nov. 27
032335	R "	July 26	"	" "	Nov. 29	124204	RU Virginis	No Max.
042209	R Tauri	May 25	072708	S Can. Min.	Oct. 26	124606	U "	May 25
042215	W "	Aug. 10	072811	T " "	Sept. 7	"	" "	Dec. 13
042309	S "	Apr. 21	*072820*b	Z Puppis	No Max.	*130212*	RV Virginis	May 31
043065	T Camelop.	May 11	073508	U Can. Min.	June 18	"	" "	Dec. 27
043208	RX Tauri	Oct. 7	073723	S Gemin.	Mar. 26	*132202*	V "	Jan. 5
043274	X Camelop.	Jan. 1	074323	T "	May 17	*132422*	R Hydrae	Aug. 27
"	" "	May 21	*075612*	U Puppis	May 1	*132706*	S Virginis	Jan. 28
"	" "	Oct. 8	081112	R Cancri	June 6	133273	T Urs. Min.	May 29
044617	V Tauri	June 1	081617	V "	Aug. 23	134440	R Can. Ven.	Nov. 7
"	" "	Nov. 20	083019	U "	June 5	*135908*	RR Virginis	June 14
045307	R Orionis	Mar. 22	083350	X Urs. Maj.	Feb. 21	140113	Z Bootis	July 4
045514	R Leporis	Jan. 1	"	" " "	Oct. 30	*140512*	Z Virginis	June 28
050003	V Orionis	July 9	084803	S Hydrae	May 26	141567	U Urs. Min.	Oct. 20
050022	T Leporis	Jan. 4	*085008*	T "	July 5	141954	S Bootis	Apr. 10
050953	R Aurigae	Sept. 12	*090024*	S Pyxidis	Mar. 1	142205	RS Virginis	June 11
052036	W "	Feb. 5	"	" "	Sept. 29	142539	V Bootis	Apr. 11
"	" "	Nov. 7	090425	W Cancri	July 24	142584	R Camelop.	Feb. 27
052404	S Orionis	Jan. 1	*093014*	X Hydrae	Oct. 14	"	" "	Nov. 24
053068	S Camelop.	Sept. 6	093178	Y Draconis	Apr. 30	143227	R Bootis	Feb. 6
053531	U Aurigae	Nov. 17	093934	R Leo. Min.	Feb. 2	"	" "	Sept. 16
054920	U Orionis	June 25	*094023*	RR Hydrae	Mar. 13	*143417*	V Librae	May 7
054974	V Camelop.	Apr. 21	094211	R Leonis	Aug. 17	144918	U Bootis	Feb. 5
055353	Z Aurigae	Feb. 11	095421	V "	May 25	"	" "	July 22
"	" "	June 3	103769	R Urs. Maj.	Aug. 11	*150018*	RT Librae	June 7
"	" "	Sept. 23	104814	W Leonis	Nov. 23	*150519*	T "	May 7
060450	X "	Feb. 17	110506	S "	Jan. 11	*150605*	Y "	Aug. 23
"	" "	July 29	"	" "	July 20	*151520*	S "	Feb. 14
061647	V "	No Max.	115919	R Com. Ber.	June 22	"	" "	Aug. 25
061702	V Monoc.	Nov. 7	120012	SU Virginis	Apr. 1	151714	S Serpentis	Aug. 27
063159	U Lyncis	No Max.	"	" "	Sept. 13	151731	S Cor. Bor.	Feb. 10
063558	S "	Aug. 19	*120905*	T "	Feb. 24	*151822*	RS Librae	Jan. 5
064030	X Gemin.	Apr. 7	*121418*	R Corvi	Jan. 31	*152714*	RU "	Apr. 20
064707	W Monoc.	June 22	"	" "	Dec. 17	153378	S Urs. Min.	Apr. 11
065111	Y "	Feb. 25	122532	T Can. Ven.	Feb. 12	*153620*	U Librae	Aug. 11
"	" "	Oct. 8	"	" " "	Nov. 21	154536	X Cor. Bor.	Feb. 14
065208	X "	Jan. 10	*122803*	Y Virginis	Apr. 11	"	" " "	Oct. 10
"	" "	June 6	"	" "	Nov. 17	154615	R Serpentis	Apr. 3
"	" "	Oct. 31	123160	T Urs. Maj.	Feb. 17	154639	V Cor. Bor.	Nov. 23

Desig.	Name.	Date.	Desig.	Name.	Date.	Desig.	Name.	Date.
		1917.			1917.			1917.
154715	R Librae	May 14	171723	RS Herculis	Jan. 4	193449	R Cygni	Oct. 4
155018	RR “	Mar. 7	“	“ “	Aug. 15	193509	RV Aquilae	July 6
155229	Z Cor. Bor.	June 10	172809	RU Ophiuchi	May 30	194048	RT Cygni	May 11
155823	RZ Scorpii	Jan. 27	“	“ “	Dec. 8	“	“ “	Nov. 17
“	“ “	July 8	175111	RT Ophiuchi	Mar. 12	194348	TU Cygni	Feb. 18
“	“ “	Dec. 17	175458	T Draconis	Nov. 19	“	“ “	Sept. 24
160021	Z “	Feb. 10	175519	RY Herculis	Mar. 19	194604	X Aquilae	May 9
160118	R Herculis	Jan. 11	“	“ “	Oct. 27	194632	χ Cygni	Mar. 16
“	“ “	Nov. 27	175654	V Draconis	May 13	*195202*	RR Aquilae	No Max.
160210	U Serpentis	July 25	180531	T Herculis	June 10	*195308*	RS “	No Max.
160524	RX Scorpii	Apr. 7	“	“ “	Nov. 22	195849	Z Cygni	May 29
“	“ “	Dec. 5	180565	W Draconis	June 8	200212	SY Aquilae	Mar. 27
160625	RU Herculis	Nov. 22	181103	RY Ophiuchi	Feb. 22	200357	S Cygni	Oct. 11
*161122*a	R Scorpii	Jan. 13	“	“ “	July 24	*200514*	R Capricorni	July 28
“	“ “	Aug. 23	181136	W Lyrae	Mar. 16	200715a	S Aquilae	Mar. 6
*161122*b	S “	May 25	“	“ “	Sept. 28	“	“ “	Aug. 1
“	“ “	Nov. 18	182224	SV Herculis	July 20	200812	RU “	Apr. 7
161138	W Cor. Bor.	Apr. 14	“	“ “	Nov. 7	*200822*	W Capricorni	June 24
“	“ “ “	Dec. 15	182306	T Serpentis	May 17	*200906*	Z Aquilae	May 1
161607	W Ophiuchi	Feb. 20	183149	SV Draconis	Aug. 3	201008	R Delphini	Jan. 5
162112	V “	Feb. 12	183225	RZ Herculis	July 30	“	“ “	Oct. 16
“	“ “	Dec. 11	183308	X Ophiuchi	Sept. 10	201130	SX Cygni	Aug. 29
162119	U Herculis	July 31	184134	RY Lyrae	Jan. 25	201647	U “	May 1
162319	Y Scorpii	June 17	“	“ “	Dec. 25	*202622*	RU Capric.	Sept. 8
162807	SS Herculis	Feb. 2	184243	RW Lyrae	Mar. 18	202817	Z Delphini	Apr. 18
“	“ “	May 19	185032	RX Lyrae	Aug. 5	202954	ST Cygni	Aug. 24
“	“ “	Sept. 2	*185512*	ST Sagittarii	Sept. 25	203611	Y Delphini	No Max.
“	“ “	Dec. 17	185634	Z Lyrae	Mar. 22	203816	S Delphini	Sept. 12
162815	T Ophiuchi	Mar. 24	190108	R Aquilae	July 11	203847	V Cygni	Jan. 1
162816	S “	Aug. 7	190529a	V Lyrae	Feb. 12	204016	T Delphini	June 11
163137	W Herculis	Jan. 21	*190818*	RX Sagittarii	July 14	*204104*	W Aquarii	Jan. 12
“	“ “	Oct. 28	190925	S Lyrae	July 15	204318	V Delphini	Apr. 18
163266	R Draconis	Aug. 14	190933a	RS Lyrae	Jan. 28	*204405*	T Aquarii	May 27
164319	RR Ophiuchi	Sept. 24	“	“ “	Nov. 21	204846	RZ Cygni	Mar. 20
164715	S Herculis	Feb. 6	190941	RU Lyrae	Nov. 22	205017	X Delphini	Mar. 18
“	“ “	Dec. 9	190967	U Draconis	Oct. 12	205923	R Vulpeculae	Jan. 26
165030	RR Scorpii	May 2	*191007*	W Aquilae	Aug. 21	“	“ “	June 12
165202	SS Ophiuchi	May 1	*191017*	T Sagittarii	Dec. 23	“	“ “	Oct. 27
“	“ “	Dec. 9	*191019*	R “	May 1	*210124*	V Capricorni	Feb. 21
165631	RV Herculis	Apr. 1	*191319*	S “	Mar. 4	“	“ “	July 28
“	“ “	Oct. 18	“	“ “	Oct. 22	“	“ “	Dec. 31
170215	R Ophiuchi	Feb. 17	*191321*	Z “	No Max.	210129	TW Cygni	June 30
“	“ “	Dec. 16	191637	U Lyrae	No Max.	210382	X Cephei	June 5
170627	RT Herculis	Mar. 13	192928	TY Cygni	Apr. 11	*210504*	RS Aquarii	Mar. 20
171401	Z Ophiuchi	Apr. 21	193311	RT Aquilae	May 8	“	“ “	Oct. 30

Desig.	Name.	Date.	Desig.	Name.	Date.	Desig.	Name.	Date.
		1917.			1917.			1917.
210516	Z Capricorni	Aug. 31	215934	RT Pegasi	Aug. 29	230759	V Cassiop.	Jan. 26
210812	R Equulei	Feb. 20	220412	T “	June 14	“	“ “	Sept. 13
“	“ “	Nov. 7	220613	Y “	Apr. 7	231425	W Pegasi	May 15
210868	T Cephei	Jan. 11	“	“ “	Oct. 30	231508	S “	May 5
210903	RR Aquarii	Apr. 23	220714	RS “	Feb. 8	233335	ST Androm.	June 23
“	“ “	Oct. 30	*221321*	X Aquarii	July 15	*233815*	R Aquarii	Oct. 14
211614	X Pegasi	Apr. 27	222439	S Lacertae	Jan. 10	233956	Z Cassiop.	Nov. 22
“	“ “	Nov. 15	“	“ “	Sept. 6	235053	RR “	July 8
211615	T Capricorni	Jan. 13	223841	R “	July 22	*235209*	V Ceti	May 21
“	“ “	Oct. 16	*225120*	S Aquarii	May 27	235350	R Cassiop.	Jan. 11
213678	S Cephei	Sept. 8	225914	RW Pegasi	Mar. 14	235525	Z Pegasi	Dec. 1
214024	RR Pegasi	Feb. 21	“	“ “	Oct. 12	235855	Y Cassiop.	June 28
“	“ “	Nov. 9	230110	R “	Jan. 13	235939	SV Androm.	May 11
215934	RT “	Jan. 26						

EDWARD C. PICKERING.

October 25, 1916.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 198.

ECLIPSES OF JUPITER'S SATELLITES.

THE observation of the eclipses of the satellites of Jupiter is easy and of much interest. It can readily be undertaken by amateurs as well as by professional astronomers. The probable error of the photometric measures described is H.A. 52 is about two seconds of time. On the other hand, the average deviation of the computed time as derived from the elaborate computation of Professor Sampson, contained in the same volume, is about seven seconds. These deviations appear to be real and not due to errors of observation. A possible explanation is that the presence of clouds in the atmosphere of Jupiter increases its apparent diameter and therefore that of its shadow. It is accordingly of much importance to determine the actual times and to confirm large deviations from theory by several independent observations. The configurations of the satellites for each evening are given in the English and American Nautical Almanac, and in several astronomical periodicals. The positions of the satellites at the time of eclipse are also given. After the opposition of Jupiter nearly all the eclipses are reappearances. It is only necessary to watch the position in which the satellite will appear and record the time in minutes and seconds with a good watch. Sometimes the satellite is suspected and a few seconds later certainly seen. If possible, both times should be recorded. The disappearances are still more easily observed, but they generally occur after midnight, before Jupiter is in opposition. It is essential that the error of the watch should be known. It can be found by calling the Observatory by telephone "Cambridge, 390" half an hour before or after the eclipse. Many jewellers obtain the time by telegraph, and by a simple wireless apparatus, the signals from Washington can be observed five minutes before noon and ten in the evening.

Table I gives a list of the eclipses visible this winter. The calendar date is followed by the number of the satellite preceded by the letters R or D, and the Eastern time of the predicted eclipse. If Central Time is used, sub-

tract one hour. These times are computed for the centre of the satellite entering the shadow. It will be first seen about three, four, and nine minutes earlier in the case of Satellites I, II, and III, respectively. The disappearances should occur later by the same amounts.

TABLE I.

ECLIPSES OF JUPITER'S SATELLITES.

Date.	Satellite.	East. Time.	Date.	Satellite.	East. Time.	Date.	Satellite.	East. Time.
1916.			**1917.**			**1917.**		
Dec. 4	R I	11 10 30	Jan. 1	R II	6 6 46	Jan. 28	R I	8 7 26
“ 6	R I	5 39 29	“ 5	R I	7 51 20	Feb. 4	R I	10 3 3
“ 7	R II	8 58 12	“ “	D III	11 33 24	“ 9	R II	8 33 9
“ 11	R I	13 6 12	“ 8	D II	6 11 9	“ 10	D III	7 45 24
“ 13	R I	7 35 11	“ “	R II	8 43 53	“ “	R III	9 25 58
“ 14	R II	11 34 41	“ 12	R I	9 47 5	“ 13	R I	6 27 27
“ 20	R I	9 30 56	“ 15	D II	8 48 31	“ 20	R I	8 22 55
“ 27	R I	11 26 41	“ “	R II	11 21 12	Mar. 8	R I	6 42 28
“ 29	D III	7 31 20	“ 19	R I	11 42 49	“ 13	R II	8 24 10
“ “	R III	9 14 20	“ 21	R I	5 11 46	“ 15	R I	8 37 39
			“ 22	D II	11 26 2	“ 25	D III	7 56 30

EDWARD C. PICKERING.

November 30, 1916.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 199.

ASTEROIDS BRIGHT IN 1917.

THE ephemerides of the minor planets for 1917, has been issued on time, as usual, by the Rechen-Institute of Berlin. For the convenience of those not having ready access to this work, facts relating to the brighter asteroids are printed here, in substantially the same form as in H. C. 189, which gives the corresponding facts for 1916. The objects selected are those which attain the magnitude 10.0, and brighter, and Sirona (116), Celuta (186), and Tercidina (345) which appear to be variable. The first five columns of Table I give the number of the asteroid, its name, the date of opposition, the magnitude at that time, and the magnitude at mean opposition. The sixth column is found by subtracting the fifth column from the fourth. Negative signs predominate and indicate that the asteroid is brighter than usual, and that conditions are therefore favorable for its observation. The next six columns give the date, the right ascension, and the declination, on the first, and on the last, date given in the Berlin ephemeris. The principal use of this table will be for observers who find a moving object on their photographs. The positions given will generally indicate whether the object is known. If bright, and not given in Table I, repeated photographs should be taken. A notification should be sent at once to this Observatory so that it may be confirmed and observed elsewhere.

Any moving object is likely to be of interest, if when near opposition its right ascension does not diminish daily by much more or less than a minute. An asteroid near the Poles of the Ecliptic, R. A. = $18^h\,00^m$, Dec. = +67° and R. A. = $6^h\,00^m$, Dec. = −67°, should be followed, since it may be very near the Earth, or its orbit may have a large inclination.

TABLE I.

ASTEROIDS BRIGHT IN 1917.

No.	Name.	Opp. 1917.	m	m_o	Diff.	Date.	R. A.	Dec.	Date.	R. A.	Dec.
							h. m.	° ′		h. m.	° ′
186	Celuta	Jan. 6	12.0	11.4	+0.6	Dec. 22	7 30.2	+42 50	Jan. 31	6 39.9	+42 46
2	Pallas	“ 25	6.7	8.0	−1.3	Jan. 15	8 38.5	−27 8	Feb. 24	8 12.9	−14 42
14	Irene	Feb. 4	8.9	9.7	−0.8	“ 23	9 23.3	+26 46	Mar. 4	8 49.4	+30 35
40	Harmonia	“ 6	9.4	9.2	+0.2	“ 23	9 34.3	+19 15	“ 4	8 56.4	+22 45
8	Flora	“ 14	9.1	8.9	+0.2	“ 31	10 8.5	+17 1	“ 12	9 30.5	+21 16
37	Fides	“ 15	10.0	10.4	−0.4	“ 31	10 7.2	+15 32	“ 12	9 32.8	+17 33
129	Antigone	Mar. 1	9.8	10.3	−0.5	Feb. 16	11 0.7	+12 53	“ 28	10 32.0	+18 26
1	Ceres	“ 12	7.1	7.4	−0.3	“ 24	11 43.5	+20 14	Apr. 5	11 12.1	+22 36
12	Victoria	“ 28	9.9	9.7	+0.2	Mar. 12	12 42.8	−15 48	“ 21	12 8.1	−10 34
5	Astraea	Apr. 3	9.1	9.9	−0.8	“ 20	13 2.4	+ 0 45	“ 29	12 34.1	+ 4 30
44	Nysa	“ 5	9.5	9.8	−0.3	“ 20	13 12.3	− 1 46	“ 29	12 40.0	+ 1 53
354	Eleonora	“ 12	9.7	10.0	−0.3	“ 28	13 35.2	+15 23	May 7	13 8.5	+18 55
63	Ausonia	“ 26	9.4	9.9	−0.5	Apr. 13	14 26.2	−23 29	“ 23	13 49.3	−21 25
433	Eros	May 1	9.9	9.7	+0.2	“ 21	14 51.5	−50 23	“ 31	13 57.9	−39 5
42	Isis	“ 22	9.9	10.4	−0.5	May 7	16 12.1	−13 51	June 16	15 32.9	−14 50
326	Tamara	“ 30	10.0	11.1	−1.1	“ 15	16 51.3	−49 32	“ 24	15 41.8	−57 1
39	Laetitia	June 5	9.6	9.5	+0.1	“ 23	17 5.0	− 6 58	July 2	16 33.5	− 6 52
51	Nemausa	July 13	10.0	9.8	+0.2	July 2	19 39.9	− 5 47	Aug. 11	19 6.8	− 9 11
7	Iris	“ 21	8.4	8.4	0.0	“ 10	20 12.0	−14 20	“ 19	19 34.1	−15 0
3	Juno	“ 26	8.9	8.7	+0.2	“ 10	20 36.4	− 3 12	“ 19	20 3.9	− 7 5
10	Hygiea	“ 28	9.2	9.5	−0.3	“ 18	20 36.7	−16 50	“ 27	20 7.9	−17 51
128	Nemesis	Sept. 7	10.0	10.6	−0.6	Aug. 27	23 12.6	−16 26	Oct. 6	22 43.7	−18 32
88	Thisbe	“ 13	10.0	10.8	−0.8	Sept. 4	23 32.2	+ 6 15	“ 14	23 4.9	+ 3 2
116	Sirona	“ 18	11.4	10.7	+0.7	“ 4	23 55.2	− 5 59	“ 14	23 25.3	− 8 45
19	Fortuna	“ 20	8.9	9.8	−0.9	“ 4	0 1.9	+ 2 13	“ 14	23 32.0	− 1 42
4	Vesta	“ 30	6.7	6.5	+0.2	“ 20	0 37.2	− 8 52	“ 30	0 5.7	−11 12
33	Polyhymnia	Oct. 1	9.6	11.8	−2.2	“ 20	0 38.4	+ 3 44	“ 30	0 15.2	+ 2 20
49	Pales	“ 5	9.6	11.0	−1.4	“ 20	0 54.2	+11 26	“ 30	0 27.1	+ 8 32
103	Hera	“ 13	9.9	10.2	−0.3	“ 28	1 25.8	+ 1 0	Nov. 7	0 56.5	− 2 14
135	Hertha	“ 17	9.7	10.5	−0.8	Oct. 6	1 37.9	+12 56	“ 15	1 6.0	+10 13
29	Amphitrite	“ 20	8.7	9.0	−0.3	“ 6	1 51.7	+16 32	“ 15	1 16.3	+14 44
471	Papagena	Nov. 17	8.4	10.1	−1.7	Nov. 7	3 41.4	+ 3 46	Dec. 17	3 7.4	+ 8 0
80	Sappho	“ 22	9.8	10.6	−0.8	“ 7	4 4.5	+16 26	“ 17	3 30.4	+11 25
28	Bellona	“ 24	9.6	10.1	−0.5	“ 15	4 5.7	+ 5 25	“ 25	3 35.1	+ 5 18
349	Dembowska	Dec. 6	9.5	9.8	−0.3	“ 23	5 5.8	+30 52	“ 33	4 28.5	+30 50
345	Tercidina	“ 9	10.9	11.2	−0.3	Dec. 1	5 12.8	+11 16	“ 41	4 39.6	+ 9 12
185	Eunike	“ 19	9.8	10.0	−0.2	“ 9	5 56.9	−10 44	“ 49	5 25.6	− 6 17

EDWARD C. PICKERING.

January 10, 1917.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR 200.

VARIABILITY OF URANUS.

In order to determine any changes which might take place in the light of the Sun, Mr. Leon Campbell undertook a series of photometric observations of the light of Uranus. This led to the discovery that the light of this planet varies by about 0.15 magn. in a period of $0^d.451$. The results of these measures are shown in Fig. 1. The photometer employed was that having achromatic prisms and described in H.A. 69, 3. The total number of settings was 2960, divided into 185 sets of 16 settings each.

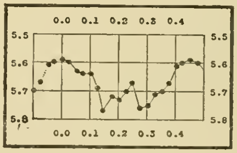

FIG. I.

It is interesting to note that the period agrees with that of rotation found by Professor Lowell and Dr. Slipher (Lowell Observatory Bulletin, 53). The latter determination was made with the spectroscope, and the photometric value was deduced entirely independently. We may, therefore, conclude that the variation in light is due to unequal brightness of different portions of the planet, and that by later photometric measures the period can be determined with a high degree of accuracy, if the variations in brightness are permanent.

EDWARD C. PICKERING.

JANUARY 25, 1917.

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